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OF THE

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PROCEEDINGS

OF THE

IRON AND STEEL INSTITUTE.

ANNUAL MEETING, 1884.

WEDNESDAY, APRIL 30TH.

THE ANNUAL GENERAL MEETING of the INSTITUTE was opened this morning at the Institution of Civil Engineers, 25 Great George Street, Westminster—B. SAMUELSON, Esq., M.P., F.R.S., President, in the chair.

The Minutes of the previous General Meeting were read, approved, and signed by the President.

NEW MEMBERS.

Mr. WALTER JOHNSON and Mr. J. E. STEAD were appointed scrutineers of the voting papers, and reported, on the completion of their scrutiny, that the following new members had been elected, viz.:—

ALLEN, H.....................................Sheffield.
BEAULIEU, HENRI..........................Pagny-sur-Meuse, France.
BOND, F. W...................................Henley-on-Thames.
BULMER, W. R..............................South Bank.
CARVÉS, F.....................................St. Etienne, France.
CHARLTON, HENRY........................Gateshead.
COLE, ALBERT...............................Brierley Hill.
COWAN, DAVID..............................Carron Ironworks, N.B.
CRAVEN, JOSEPH...........................Sheffield.

Cuninghame, A .... Coatbridge. N.B.
Darby, Alf. .... Brymbo, Wrexham.
Dyer, H. S .... Newcastle-on-Tyne.
Dymond, T .... Barnsley.
Edmonds, R .... Woolwich.
Ellis, T. L .... Coatbridge.
Evans, R. R .... Rotherham.
Fownes, Hy .... Newcastle-on-Tyne.
Geen, George .... Newport, Mon.
Gill, George .... Walsall.
Griffith, W .... South Yorkshire.
Haggie, D. H .... Sunderland.
Harbord, F. W .... Wolverhampton.
Helder, Augustus .... Whitehaven.
Hellon, Robert .... Stockton-on-Tees.
Heslop, C .... Skelton, Yorkshire.
Hodges, P. .... Sheffield.
Jacks, W .... Glasgow.
James, J. W. Hy .... Westminster, S.W.
Jameson, John .... Newcastle-on-Tyne.
Kennard, H. K .... London.
Kidner, Jno .... Thrapston.
Koehler, E. .... Bochum, Westphalia.
Macalpine, G. W .... Parkside, Accrington.
Macarthy, G. E .... Newcastle-on-Tyne.
McCorkindale, R .... Holytown, N.B.
McCowan, William .... Workington.
McLaren, W. B .... Bradford.
Menzies, W .... Glasgow.
Molineux, W. .... Moxley.
Nash, H .... Liverpool.
Oliver, D. B .... Pittsburg, U.S.A.
Oliver, H. W., jun .... Pittsburg, U.S.A.
Otto, Dr. K .... Dalhausen, Germany.
Panton, W. H .... Stockton.
Pease, Arthur, M.P. .... Darlington.
Pierce, J. J. .... Pennsylvania, U.S.A.
Proudlock, M .... Middlesbrough.
Robson, Neil .... Glasgow.
Rowan, F. J. .... Glasgow.
Russel, C. G .... Workington.
Schulz, G. .... Bochum, Westphalia.
Smith, W. A .... Northampton.
Soldenhoff, Richard De .... Merthyr Tydfil.
Somers, Walter .... Birmingham.
Sorby, T. W. .... Sheffield.
Spencer, J. C. .... Newcastle-on-Tyne.
Storey, E .... Leigh.
Thompson, J .... Stockton-on-Tees.
Tolmie, D. T .... Glasgow.
Turton, George .... Westminster, S.W.
Turton, John .... Sheffield.
Wilson, A. E .... Brigg, Lincolnshire.
Witherow, J. P. .... Pittsburg, U.S.

REPORT OF COUNCIL FOR 1883.

The following Report of the Council for 1883 was read by the Secretary:—

The Council, in presenting its Fifteenth Annual Report, has pleasure in being able to congratulate the members on the continued prosperity of the Institute, alike as regards its numbers and its financial position.

The total number of new members elected during 1883 was 131. Sixty-eight names were removed from the Register during that year, in consequence of death and other causes, leaving a net increase of sixty-three. The number of candidates on the voting list for the present meeting is sixty-three, which, if all are elected, will increase the number of members to 1332.

Of the 131 new members elected in 1883 thirty-one reside out of the United Kingdom, a circumstance which shows the estimation in which the Institute is held by metallurgists in other countries.

During the year 1883 the following members were removed by death, viz.:—

John Adams.
H. G. Bolam.
J. Cosgrove.
G. Denholm, sen.
A. Durieux.
R. R. Greene.
Miles Kennedy.
S. Lancaster.
John Paton.
Joseph Piper.
T. G. Richardson.
Sir H. W. Ripley.
J. F. Seddon.
James Shaw.
Sir C. W. Siemens, F.R.S., &c.
William Smith.
George Wood.

Your Council have been deprived of a colleague whose fame shed lustre on the Institute by the death of their past President, Sir C. William Siemens. He assisted in its establishment, and never ceased to promote its welfare.

The Council have also to announce with regret the decease of Mr. Charles Bagnall, of Sneaton Castle, Whitby, who had been one of their colleagues since 1870, and of Mr. John Lancaster, of Bilton Grange, Rugby, who had likewise been a member since 1870.

Mr. William Evans of Bowling has been elected to fill the vacancy in the list of Vice-Presidents created by the election of Mr. Samuelson as President of the Institute.

Two general meetings of the Institute were held during the year 1883—the Spring Meeting in London, and the Autumn Meeting in Middlesbrough—at which the following papers were read and discussed :—

On the Use of Steel Castings in Lieu of Iron and Steel Forgings for Ship and Marine Engine Construction. By Mr. WILLIAM PARKER, Chief Engineer of Lloyds' Register of Shipping.

On Bessemer Steel in its Cast and Unwrought State. By Mr. W. D. ALLEN, Sheffield.

A Comparison of the Working of a Blast Furnace with Blast varying in Temperature from 990° Fahr. to 1414° Fahr. By Mr. W. HAWDON, Middlesbrough.

On the Value of Successive Additions to the Temperature of the Air used in Smelting Iron. By Mr. I. LOWTHIAN BELL, F.R.S.

On the Northampton Iron Ore District. By Mr. W. H. BUTLIN, B.A., Camb.

On a New Method for the Estimation of Minute Quantities of Carbon, and a New Form of Chromometer. By Mr. J. E. STEAD, Middlesbrough.

On the Production and Utilisation of Gaseous Fuel in the Iron Manufacture. By Mr. W. S. SUTHERLAND, Birmingham.

On Improvements in Railway and Tramway Plant. By M. ALBERT RICHE, Belgium.

On the Tin Plate Industry. By Mr. E. TRUBSHAW, Llanelly.

On the Coal-Washing Machinery used by the Bochumer Verein. By Herr F. BAARE, Bochum.

On the Manufacture of Anthracite Pig Iron. By Mr. J. HARTMAN, Philadelphia, U.S.A.

On the Cost and the Results of the Manufacture of Coke on the Simon-Carvés System at the Collieries of Messrs. Pease, Pease's West, Durham. By Mr. R. DIXON, Pease's West.

On the Jameson System of Coke Manufacture. By Mr. J. JAMESON, Newcastle-on-Tyne.

On Recent Improvements in Cowper Hot-Blast Fire-brick Stove. By Mr. E. A. Cowper, M.I.C.E., Westminster.

On Blast Furnace Economy in Relation to Design. By Mr. R. Howson, Middlesbrough.

On a New Centre Crane for Bessemer Steel Works. By Mr. T. Wrightson, M.I.C.E., Stockton.

On Different Systems of Hydraulic Cranes for Bessemer Steel Works. By Mr. R. M. Daelen, Düsseldorf.

The Autumn Meeting at Middlesbrough was the most numerously attended that the Institute has yet held, upwards of 400 members and 100 visitors having been present, including a large number of foreign metallurgists. The arrangements made for that meeting by the Local Committee greatly contributed to the convenience of members; and the Council desire to recognise the efforts made on that occasion, not alone by the Local Committee, but by the North-Eastern Railway Company, and various other Corporations connected with Tees-side.

The lamentable accident that occurred at the North-Eastern Steel Works during the Middlesbrough Meeting, whereby a member of the Institute, Mr. S. Davison, lost his life, induced the Council to make an appeal to the members of the Institute on behalf of the widow and family of that gentleman. That appeal has resulted in the collection of a sum of £1466, which has been invested for the benefit of Mr. Davison's family. A list of subscriptions will shortly be issued to the subscribers.

In their last Annual Report, the Council announced that they were taking the necessary steps to establish a Reference Library for the use of the Institute. The Library is now open. The Council have to acknowledge the gift, by Lady Siemens, of a number of metallurgical works which formed part of the library of her late husband, and by the Reception Committee of the London Autumn Meeting of 1881 of its surplus funds, which have been invested in books. The Library now contains upwards of 1500 volumes, including a collection of tracts relating to mining and metallurgy. Two rooms have been fitted up at the Offices of the Institute for the use of members, in which the principal English and foreign periodicals of interest to metallurgists will be found.

The Council will be glad of any contributions from members which will make the Library more complete.

The Council have arranged to hold the next Autumn Meeting at Chester.

The Council have decided to award this year two Bessemer medals, to Mr. E. P. Martin and Mr. E. Windsor Richards, respectively.

The retiring members of Council are :—

Vice-Presidents.

Mr. James Kitson, jun. Mr. Charles Markham.
Mr. John Lancaster.

Members of Council.

Mr. D. Adamson. Mr. G. J. Barker.
Mr. W. T. Crawshay. Mr. W. Jenkins.
Mr. E. W. Richards.

No other nominations having been received, the Council propose the re-election of their retiring colleagues. The filling up of the vacancy caused by the decease of Mr. Lancaster will receive due consideration.

Mr. DAVID DALE, the Hon. Treasurer, submitted the Financial Statement for 1883, which appears in the Appendix.

The PRESIDENT said he did not know that the Report required any observations from him. He might mention, however, that Mr. Alfred Hewlett had been nominated and accepted by the Council, subject to confirmation at a future meeting, as being a desirable gentleman to fill the vacancy caused by the death of Mr. Bagnall, which they all very much regretted. Mr. Hewlett represented the district of Wigan, which was a very important one. He was manager of the ten blast furnaces of the Wigan Coal and Iron Company, and the Council thought his assistance would be valuable to the interests of the Institute.

The Report mentioned the amount of subscription raised for the family of Mr. Davison. The investment of the fund so raised had been kindly undertaken by Mr. Whitwell, and although a circular giving full particulars would be issued shortly to the members, it might be interesting if, before the resolution for the adoption of the Report was carried, Mr. Whitwell would kindly state generally what were the steps that had been taken in regard to the fund so raised.

Members would have noticed that Chester had been chosen as the meeting-place in the autumn. It was true that at Chester they would not find themselves in immediate contact with large metallurgical works, still it was a convenient centre for excursions to objects of great interest to them as iron and steel manufacturers. He need only mention Crewe, for instance, which was always interesting, no matter how often it was visited. There were also the iron works of North Wales, which they had not yet seen; and, as an object of general interest, there was the new tunnel under the Mersey, which he thought would be interesting to many members, while he need hardly say that in Birkenhead and Liverpool there were many objects which, he was sure, would be visited with pleasure by the members. It appeared to the Council that their autumn meetings might be rendered—occasionally at any rate—rather meetings for relaxation than for that close attention to the pursuits of the members which had hitherto characterised them, and it was hardly possible to conceive of any place from which more delightful excursions could be made, provided they were favoured with moderate weather, than from Chester. The Council hoped, therefore, that the choice of Chester as the meeting-place of the members in the ensuing autumn would commend itself to the Institute. He did not know that he had any further remarks to make.

Mr. W. Whitwell reported that the invitation issued by the Council to subscribe to the Davison Fund had been most liberally responded to. The amount now in hand was slightly above £1450, and subscriptions were still coming in. He had received that morning £5, and expected a cheque for £20 on the following day. A trust deed had been prepared, and was only awaiting the signature of one of the trustees, when the matter would be completed. The trustees selected were Mr. William Davison of Wakefield, brother of the deceased; Mr. Williams, solicitor, also of Wakefield; and Mr. Willis of Newcastle-upon-Tyne, brother of the widow, and one of Her Majesty's Inspectors of Mines. Those three would have entire power over the fund, and the interest would be devoted to the benefit of the family for the present. The trustees would have authority to dispose of and divide the fund in such proportions as they might think most reasonable

amongst the five children. There were four boys and one daughter. The education of the two youngest children would have to be completed, and it was possible that a portion of the funds might be used for that purpose. It was, no doubt, the intention of the subscribers that the funds should be made most useful both to the widow and to the children, and hence there was considerable latitude left to the trustees, who were all men of standing and integrity, and it had been felt that to leave them in absolute charge of the funds would best serve the interests of the family, as well as provide for the wishes of the subscribers being carried out. He thought he could assure them that the funds that had been so liberally raised would be of very great benefit to the family, and they had been received with most grateful acknowledgment.

The PRESIDENT formally moved that the Report and Statement of Accounts be adopted.

Mr. I. LOWTHIAN BELL seconded the motion, which was agreed to.

Mr. BOLCKOW said he was sure that the members, after having heard the Report which had just been read, and the very satisfactory Statement of Accounts, would agree with him that they owed a debt of gratitude to the President and Council of the Institute. The President had been most successful in increasing the number of members, and to him, therefore, specially, and next to the Council, he thought that their hearty thanks for their services during the past year were due.

Mr. J. CORNER seconded the motion, which was unanimously agreed to.

The PRESIDENT, on behalf of the Council, and on his own behalf, thanked the members very sincerely for the kind way in which they had received the proposal of a vote of thanks. He was sure they were aware that every member of the Council, both in his interests and in his sympathies, was entirely at one with the objects for which their Institute was founded, and which, he believed, it was thoroughly well fulfilling. Mr. Bolckow had said that the increase in numbers of the Institute was due to its

President, but it was no more due to its actual President than to all its preceding Presidents. There had been no interruption in the prosperity, or in the increase in the number of members of the Institute, and so long as it fulfilled its functions worthily, which he trusted, and indeed he was sure, it would always do, he believed that it would go on and prosper. He thanked them exceedingly, in the name of the Council and in his own name, for the vote of thanks which had been proposed and accepted.

On the motion of Mr. Jeremiah Head a cordial vote of thanks was accorded to the Hon. Treasurer for his valuable services during the past twelve months.

Mr. Dale, in acknowledging the compliment, intimated that it would be a great convenience, both to the Secretary and to himself as Hon. Treasurer, if members remitted their subscriptions direct to him, instead of sending them through the Secretary.

The Bessemer Medals for 1884.

The President said that members would have noticed in the Report of the Council, which had been read and adopted, that it was proposed to present the Bessemer medals for this year to Mr. Martin and Mr. Windsor Richards. He now called upon those gentlemen to come up in order to receive the medals. [Mr. Martin and Mr. Windsor Richards approached the table, as requested.] On the occasion of their last Spring Meeting, the Council presented Bessemer medals to Mr. Snelus and to Mr. Thomas, as a recognition of the great services which they had rendered to the craft by their discovery of a means of utilising, for the production of steel and homogeneous metal of a high class, crude iron contaminated with phosphorus and other impurities. He need not revert to the great merit of that discovery, and its very great use to metallurgy, because those were matters which had been fully discussed, and which he thought, at the present day, were fully acknowledged. But whilst great credit was due to those gentlemen as inventors, it was, he thought, equally obvious that unless

metallurgists of reputation had been prepared to take their invention, to give it the sanction of their experience, and to facilitate the necessary experiments which must precede the adoption, commercially, of any new process, that process might still have lingered in some obscurity. It was due to Mr. Martin, in the first instance, that the process, as rediscovered, if he might use the term, by Mr. Thomas, after it had been originally put in operation by Mr. Snelus—it was due to Mr. Martin that this process was duly appreciated, and that the means were furnished to Mr. Thomas for carrying on those practical experiments which enabled him to demonstrate the commercial value of the process. He thought that more than this even might be said of the services which Mr. Martin had rendered; because he (the President) had no doubt that his metallurgical experience had enabled him to shorten the path to success of that great invention. But when this had been done by Mr. Martin, all had not been done. Mr. Richards then stepped in. Mr. Richards was—he was going to say the dictator, but at any rate he was the influential director of the great works of Messrs. Bolckow & Vaughan, and the administrator, in regard to the practical portion of those works, of their enormous capital. Mr. Richards stepped in, and with a perseverance and a courage which had, perhaps, seldom been equalled in the history of metallurgy, had put a process, the utility of which had been only partially acknowledged, to the test of commercial success. That success had been achieved, thanks almost, he might say, exclusively to the energy, and perseverance, and courage of Mr. Richards. It had been considered proper, therefore, by the Council that a recognition should be made of the merits of those two gentlemen in the introduction of the basic process. They were unwilling to distinguish, and in fact they were unable to distinguish, between their respective merits, and, with the sanction of Sir Henry Bessemer, it had been concluded that, as in the case of Mr. Snelus and Mr. Thomas, so in the case of Mr. Martin and Mr. Richards, medals should be presented to each of them. He had now the honour and the pleasure to present to Mr. Martin and to Mr. Richards the Bessemer medals for the year 1884.

Mr. E. P. Martin thanked the Council for the great honour

conferred on him by awarding him the Bessemer medal, in conjunction with his friend, Mr. Windsor Richards. During his life it had been his aim and endeavour, to the best of his ability, to advance the interests of the iron and steel industries. He had been fortunate in having assisted, especially at the outset, in bringing the very important process now known over the world by the names of its two inventors, as the Thomas and Gilchrist process, to the front—a process which, notwithstanding the present large production by it of his friend, Mr. Richards, was still in its infancy. He was proud to feel that the Institute, by giving him the Bessemer medal, enabled him to rank with other Dowlais men, such as Messrs. Menelaus, Edward Williams, Jenkins of Consett, Evans of Bowling, and last, but by no means least, with Mr. Windsor Richards, who, like himself, was born and bred at Dowlais.

Mr. E. Windsor Richards said he highly appreciated the honour which the Institute had conferred upon him by the presentation of the Bessemer medal; and he valued it the more seeing that he had worked the best days of his life at that process of steel-making which bore the name of the donor of the medal. As regarded the part which he had taken in the development of that process, no doubt the difficulties, and anxieties, and cost had been great, but for those he had been amply rewarded by the success which had attended the process. The process seemed at first to develop somewhat slowly. In the year 1880 their then President stated that at that time there was no basic steel being made at Eston; to-day there was a very great and satisfactory contrast to that statement, for they were making 3000 tons of ingots per week (working five days weekly) from Cleveland ironstone. They had lived down, to a great extent, the prejudice which existed, and naturally existed, in the minds of those having the responsibility of lives and property upon their shoulders. In all undertakings it seemed to him that some one name stood out more prominently than another, and in that Bessemer lime process no name stood out so prominently, in his mind, as deserving the highest place of honour, as that of Sidney Thomas. He was sure they would all regret that the anxieties and trouble connected with that process had injured the health of Mr. Thomas. He trusted that Mr. Thomas would soon return

in restored health to take part in their discussions. It was pleasing to him to be associated with Mr. Martin in that presentation, for it was that gentleman who, with Mr. Gilchrist, had shown him, at Blaenavon, an experiment which gave him reason to believe that phosphorus could be eliminated at a high temperature. He was sure that the name of Mr. Gilchrist should also be placed high on the list of those who deserved honour for the development of that process, for by his perseverance and energy he had contributed greatly to its success.

Sir HENRY BESSEMER said he had not intended to address the meeting on the present occasion, but he thought it due both to Mr. Richards and to Mr. Martin that he should say a word or two on the subject. Since the medal had been instituted, it had never, to his mind, been more satisfactorily awarded than when it had, as now, been presented to the inventors and promoters of that great invention which bore two or three names, that he would not attempt to distinguish by putting one before the others, but the names of men who were working with great chemical knowledge, great industry, and great perseverance, and who had succeeded in doing that which had baffled him for years. It was with great pleasure that he now saw the success which had attended their improvements founded on his original process, and saw also that their inventions had been recognised in so unqualified a manner by the meeting. He assured them that he was in accord with every word that had fallen from the President, and he wished to express his great satisfaction at the award of the medals on that occasion.

The PRESIDENT, before calling upon Mr. Lowthian Bell to read the first paper, mentioned that, in addition to the papers on the list, one was promised by Mr. Walter Browne upon the steel sleepers which had been laid down by Mr. Webb on the London and North-Western Railway.

The following paper was then read:—

ON THE USE OF RAW COAL IN THE BLAST FURNACE.

By Mr. I. LOWTHIAN BELL, F.R.S.

In the various communications which have been read at the meetings of this Institute upon the consumption of fuel in the blast furnace, coke alone has been considered as the source of heat. This has partly arisen from the fact that the papers dealing with the question have generally emanated from quarters where raw coal is seldom or never used, and partly because the subject is greatly simplified when we have not to consider the behaviour of the vast amount of volatile substances which accompanies the use of uncoked coal.

This latter form of fuel, however, as used in smelting iron, has a very wide application; and having regard to this and to the circumstance that its use has received no attention on the part of the Institute, the Council invited me to prepare a short paper on the question.

Although fossil coal, as met with in Great Britain, is generally associated with a large percentage of volatile substances, the latter, in any great quantity at least, are not everywhere present. Thus the variety of coal known as anthracite is met with in the United States occasionally containing as much fixed carbon as the best Durham coke. More commonly, however, hydrocarbons are found in the produce of the Pennsylvanian pits in quantity varying from 5 to $7\frac{1}{2}$ per cent. The actual composition of this form of fuel will be best seen by referring to analyses taken from a paper by Mr. Persifor Fraser, to be found in vol. vi. p. 430 of the "Transactions of the American Institute of Mining Engineers."

Fixed Carbon. Per cent.	Volatile Matter. Per cent.	Ash, Water, &c. Per cent.
94·10	1·40	4·50
92·07	5·03	2·90
90·20	2·52	7·28
88·20	7·50	4·30

Such a specimen as that at the head of the list may be regarded, chemically speaking, as a natural coke, and its behaviour in the blast furnace, as a chemical question, cannot greatly differ from that of coal which has had its volatile constituents expelled before it reaches the smelter.

Closely as some examples of anthracite may resemble in composition the best qualities of coke, I never met in the United States any case where the duty performed by the former was equal to that generally obtained from the latter. Thus in one case described by Mr. Thomas Witherbee, in which the rich ores of Lake Champlain were smelted, 23 cwts. were consumed for each ton of Bessemer iron. The blast had a temperature of 1375° F., and the furnace itself had a height of 70 feet.

It is no doubt possible that the anthracite employed by Mr. Witherbee may have been less rich in fixed carbon than the best specimen with which we are comparing it. At the same time this particular variety of coal being prone to splinter and crumble away on exposure to heat, it is possible that the presence of an undue quantity of small coal may interfere with that uniform action of the gases on the materials which is recognised as being essential for the economical conduct of the operation. That the condition of the contents of a furnace using anthracite differs from one fed with coke seems apparent from the fact that the blast, to force its way through the materials, requires to be much more highly compressed than is ever met with in our own country. During my visits among the Pennsylvanian furnaces this pressure frequently amounted to 8 to 10 lbs. on the square inch, and I have met with it as high as 12 lbs.

From whatever cause, I doubt whether it would be safe to consider the duty capable of being afforded by the average run of anthracite as received at the furnace, apart from what may be indicated by actual chemical composition, as less than 10 per cent. below that obtained from the best Durham coke.

The hardness and density of the American anthracite are such that the produce of the mine requires to be dealt with in a peculiar fashion. The coal as it reaches the surface has the largest blocks separated from the remainder, and it is these which alone are taken for blast furnace use. The smaller coal is roughly broken, and passed through rotating riddles, so as to secure uni-

formity of size according to the purpose for which it is destined. A considerable quantity, 10 to 20 per cent. of the whole, of very small coal is thus produced, and at the time of my visiting the collieries was considered as worthless. So unwilling are the ironworks managers to admit anything but large into the furnaces, that any small made in handling the coal after it leaves the pit, amounting to about 5 per cent., is rejected.

It is not, however, with such a material as anthracite that I wish particularly to occupy your attention. Mechanically, no doubt, it differs greatly from coke; but as to chemical behaviour in the blast furnace, they closely resemble each other. I have, however, felt it necessary to allude to the subject, seeing that in the United States in the year 1882 no less than 2,042,138 tons (or 39 per cent. of the entire make) was produced by means of this variety of fuel.

The chief object of the present communication is to consider the differences between bituminous coal and coke in the smelting of iron, and to compare their respective action.

If we measure the value of these two substances in a calorific point of view when both are fully oxidised, there is but little difference between them; the value being ascertained by the power possessed to raise the temperature of a given quantity of water.

Full oxidation or complete combustion means, in the case of coke, the conversion of all the carbon into carbonic acid, and in the case of coal its conversion into carbonic acid and water.

For the purpose of illustration a specimen of coal from the Brockwell seam at a South Durham colliery will be taken; its calorific power will first be estimated in the raw state, and then a similar calculation will be applied to the coke made from the same coal.

	Composition of the Coal.	Estimated Composition of Coke from the same Coal.
	Per cent.	Per cent.
Carbon	82·27	92·44
Hydrogen	4·68	...
Oxygen	5·66	...
Nitrogen	·91	...
Water	1·00	...
Sulphur	1·22	1·00
Ash	4·26	6·56
	100·00	100·00
Fixed carbon	72·89	92·44
Volatile above 100° C. (212° F.)	20·84	nil.
Volatile below 100° C.	1·00	nil.

Heat Development from each Unit of Fuel.

	Coal.	Coke.
Carbon to carbonic acid .	·8227 × 8,000 = 6581 cals.	·9244 × 8000 = 7395 cals.
Hydrogen to water . .	·0468 × 34,000 = 1591 ,,	nil. ,,
Total developed .	8172	7395 ,,
Deduct heat absorbed by expulsion of—		
Water	·0100 × 540 = 5	nil.
Hydrocarbons, etc. (including deficiency in heat development of C and H through combined O) . . .	·2084 × 2000 = 417	nil.
	422	7395
Net heat development * .	7750	

By these computations it will be remarked that practically the heating power of coal and coke of the composition just given is the same; but as it may be satisfactory to have their correctness confirmed by actual experiment on the large scale, I will give the results of a trial recently made at my request by Mr. M'Donnell, the locomotive superintendent on the North-Eastern Railway.

I would first observe that this gentleman furnished me with the pounds of coal burnt per train mile on nine of the great railways of the United Kingdom during the half-year ending 30th June 1883. These vary considerably according to the character of the traffic, nature of the ruling gradients, and probably, to some extent, according to the quality of the fuel employed. The lowest is 32·45 lbs. per mile, and the highest 47·02 lbs., the average of the whole being 42·21 lbs. per train mile.

Two lengths of road were selected on the North-Eastern system for the experiments. The same engines were used at both localities in the two sets of experiments; the trains consisted of the same number of waggons in the trials of coal and coke, and the loads were practically the same also. The trials were continued for one week with each kind of fuel, full loads being

* No credit is taken for the heat evolved by the combustion of the sulphur in either case, because the exact form in which it exists was not determined. Besides this, the heat evolved by the oxidation of sulphur is very small, and consequently its omission does not seriously affect the calculation. The water in the coke is also neglected, but this at Durham is also very insignificant in quantity.

taken to the place of shipment, and the waggons returned empty to the collieries.

	Coal.	Coke.
One week's trial of each fuel; pounds consumed per train mile	40·5	41·6
One week's trial of each kind of fuel; pounds consumed per train mile *	37·0	42·2

The parity of results observed in burning coal and coke on a grate where the combustion is, generally speaking, perfect, is not to be found in blast furnace experience, for the simple reason that the volatile constituents are only to a small extent oxidised in the furnace, and consequently little useful effect is obtained from their presence. This statement presupposes that the smelting operation is conducted in a close-topped furnace; but in cases where the escaping gases are not utilised, the combustion on the mere upper surface of the materials is attended with little or no benefit.

There is, however, another way in which the volatile hydrocarbons might be useful in the blast furnace, viz., as a means of reducing the oxide of iron to the metallic state.

Reverting for a moment to the action of a blast furnace using coke, this first stage in the operation of smelting iron may be performed by one of two processes. Carbonic oxide generated by the combustion of carbon at the tuyeres may be the reducing agent, in which case carbonic acid is the product; or else the operation may be effected by solid carbon, in which case carbonic oxide is generated. In the latter case, not only does the carbon which has served for the purpose of reduction never reach the tuyeres, and in consequence acts no part in fusing the iron and slag, but since the heat generated by a unit of carbon leaving the furnace as carbonic oxide and as carbonic acid is respectively as 2400 to 8000, there is a great loss in the heating power of the fuel employed.

The statement just made is of course an argument for seeking to obtain as large a proportion as possible of carbonic acid in the escaping gases. Experiment and practice, however, have demonstrated that the power of carbonic oxide to reduce an oxide of iron to the metallic state has its limits; and that when something like one-third of this gas is saturated with oxygen, *i.e.*, has become

* The coal in this trial contained only 1·2 per cent. of ash against 7·4 per cent. in the coke. In both trials the coal and coke were from the same colliery, viz. Eldon and West Wylam.

carbonic acid, further change is suspended. We have then the carbon gases in their ultimate form composed of one volume of carbonic acid and two volumes of carbonic oxide. It might, however, be possible to dispense with a portion of the carbonic oxide, and still maintain the reducing power of the mixture by substituting for it a gas also capable of deoxidising the ore. The hydrocarbons, like the oxide of carbon, are energetic reducing agents; but it will be seen by a study of the composition of the escaping gases, as well as by a consideration of the quantity of fixed carbon present when raw coal is used in the blast furnace, that they do not render any marked service in the process itself.

I have been permitted, through the courtesy of a friend, to examine with all the necessary care the working of blast furnaces using the celebrated splint coal of the Lanarkshire coal-field. The information thus obtained I propose to employ for the purpose of illustrating the subject of the present paper, selecting for this purpose the performance of a furnace having a height of 74 feet, and blown with air having a mean temperature of 800° F. (427° C.)

Numerous specimens of the coal itself were collected, so as to obtain an average sample. This, as well as average samples of the escaping gases, were carefully analysed by Mr. Rocholl in the Clarence laboratory, and I would first direct your attention to the composition of the coal as thus ascertained:—

Analysis of Scotch Splint Coal.

	Per cent.			
Water given off at 100° C. (212° F.)	11·62			
Carbon	66·00	namely, 53·41 fixed, and	12·59	volatile.
Hydrogen	4·34		4·34	,,
Oxygen	11·09		11·09	,,
Nitrogen	·94		·94	,,
Sulphur*	·59		...	
Ash	5·42		...	
Total	100·00	Matter volatile above 212° F.	28·96	

As a source of heat, the chemical composition of this coal indicates a great inferiority as compared with the analysis already given, p. 3. Instead of 82·27 per cent. of carbon and 4·68 per cent. of hydrogen, it only contains 66·00 and 4·34 of these substances respectively. Again, while the English coal only shows 1·00 of water and 5·66 of combined oxygen, we have in the Scotch

* A portion, probably one-half, of the sulphur is volatile; but in the calculation this is neglected.

11·62 of the former and 11·09 of the latter. Computed in the manner applied to the South Brancepeth coal in p. 4, the heating power of the Scotch splint stands thus:—

Carbon to carbonic acid	·0066 × 8,000 =		5280
Hydrogen to water	·0434 × 34,000 =		1476
Gross heat developed			6756
Expulsion of water	·1162 × 540 =	63	
Expulsion of hydrocarbons, &c. (including deficiency in heat development of C and H through combined O)	·2896 × 2000 =	578	
			641
			6115

It thus appears that the South Durham coal possesses nearly 27 per cent. more of heating power than the splint coal just referred to.

In order to estimate the manner in which this coal performs its work in the blast furnace, specimens of gas were collected over a period of three hours, so as to secure a sample of average composition. At the same time the moisture was determined, some cubic feet of gas were specially treated for the estimation of ammonia and tarry substances. The following figures contain the results of analysis by volume and by weight:—

		By volume, per cent. of dry gas.	By weight, per cent.
Carbonic acid	CO_2	6·29	9·66
Carbonic oxide	CO	29·04	28·36
Light carburetted hydrogen	CH_4	2·84	1·59
Heavy do. do.	C_2H_4	·24	·23
Hydrogen	H	6·83	·48
Nitrogen	N	54·63	53·34
Ammonia	NH_3	.13	·07
Water	H_2O	...	6·27
		100·00	100·00
Tarry matter per 100 of gas			·93
100 volumes CO are accompanied by volumes CO_2		21·53	...
100 volumes CO, CH_4, C_2H_4, and H are accompanied by volumes CO_2		16·06	...
Carbon in carbonic acid by weight is		...	2·63
Carbon in carbonic oxide by weight is		...	12·15
Proportion of C as CO_2 to C as CO by weight is as		...	1 to 4·62

The consumption per 20 units of pig iron was as follows:—

	Units.
Raw coal in the furnace	42·39
Ironstone	37·46
Limestone	10·93

The average of fourteen observations, taken over a period of thre hours, showed the escaping gases to have a temperature of 190 C. (374° F.), while the blast averaged 427° C. (800° F.)

The carbon delivered to the furnace per 20 units of iron wa as follows:—

Fixed carbon in the coal used		22·65
Carbon in the hydrocarbons		5·34
„ limestone		1·31
		29·30
Deduct carbon absorbed by pig iron	·70	
„ in tarry matter condensed	1·38	
		2·08
Carbon in escaping gases		27·22

From these data the weight of the escaping gases per 20 unit of iron has been computed to be as follows:—

		Carbon.	Oxygen.	Hydrogen.	Nitrogen
Carbonic acid	16·26 =	4·43	11·83	...	...
Carbonic oxide	47·73 =	20·45	27·28	...	...
Light carburetted hydrogen	2·67 =	2·01	...	·66	...
Heavy do. do.	·38 =	·33	...	·05	...
Hydrogen	·81 =	...	...	·81	...
Nitrogen	89·77 =	...	...	...	89·77
Ammonia	·11 =	...	...	·02	·09
Water	10·55 =	...	9·38	1·17	...
	168·28	27·22	48·49	2·71	89·86
Tarry matter	1·56	1·38	·03	·15	...
	169·84	28·60	48·52	2·86	89·86

The quantity of heat evolved and appropriated is ascertaine by the following calculations, while for the purpose of compariso there are placed alongside these figures those which express th duty performed by a furnace using 22·32 units of coke whe smelting Cleveland calcined ironstone, the actual carbon in th coke employed being 20·40 units:—

	Raw Coal.	Cok
Fixed carbon consumed per 20 units of iron, viz., that in 42·39 units of raw coal containing 53·41 per cent. = 22·65 and in coke 20·40	22·65	20·4
Deduct carbon carried off with an equal weight of carbon in limestone	1·31	1·(
Leaves carbon to evolve heat . . . Units	21·34	18·7

Heat evolved.

	Raw Coal. Calories.		Raw Coal. Calories.
Burning the above fixed carbon to carbonic oxide gives	21·34 × 2,400 = 51,204		18·76 × 2,400 = 45,024
Of this C as CO, the part oxidised to CO_2 gives	4·43 × 5,600 = 24,808		6·52 × 5,600 = 36,512
Of the hydrogen the part burnt to water gives	*·55 × 34,000 = 18,700		nil. ...
Heat contained in the blast	... 11,920		... 11,919
Total heat evolved	...	106,632	... 93,455

Appropriation of the Heat.

			Calories.	
Class I. :—				
Fusion of slag	10,054		16,720	
Decomposition of water in the blast	3,162		2,720	
Expulsion of carbonic acid in the minerals	4,044		5.054	
Decomposition of ,, ,,	4,192		5,248	
Evaporation of water in coal and ore	3,051		312	
Expulsion of 12·28 units of hydrocarbon from coal	24,560		nil.	
		49,063		30,054
Class II. :—				
Reduction of peroxide of iron	32,710		33,108	
Carbon impregnation	1,680		1,440	
Reduction of silica, phosphoric acid, and sulphuric acid, the respective bases being found in the pig iron	4,266		4,174	
Transmission through the walls of the furnace	5,487		3,658	
Fusion of the pig iron	6,600		6,600	
Carried off in tuyere water	1,818		1,818	
		52,561		50,798
Class III. :—Carried off in escaping gases		8,953		11,043
		110,577		91,895

There is, it will be perceived, a certain discrepancy between the two sides of the accounts, the somewhat large amount of which, in the case of the furnace using raw coal, being most likely due to the factor adopted for heat absorbed in the expulsion of the hydrocarbons, viz., 2000 calories per unit, which has so far not been determined with the desirable accuracy, and to the difficulty experienced in the estimation of moisture and tarry matter —the latter including some coal dust—for which, owing to the impossibility of separating them perfectly from each other, the strictest correctness cannot be claimed.

* H charged as H_2O in moisture of coal and ore $= \frac{4·92}{9} + \frac{·73}{9} = ·62$

H discharged as H_2O in waste gases $= \frac{10·55}{9} = 1·17$

Difference = H oxidised in furnace $= ·55$

I would now direct your attention to the salient points difference in the performance of the two furnaces. We have the case of the one using raw coal a much less perfect oxidatic of the carbon, and in consequence a much smaller evolution heat. The calories or heat units due from this source are follows:—

Raw coal,	21·34 units	gave	76,012 calories	= 3562	calories per unit of fixed carbc
Coke,	18·76 ,,	,,	81,536 ,,	= 4346	do. do.

The heating power of the carbon is, however, largely suppl mented by the oxidation of ·55 units of hydrogen, which afforc by its combustion 18,700 calories. Taking the carbon—21·3 units—and this ·55 unit of hydrogen, we have 21·89 units, givir 94,712 calories—equal therefore to 4327 calories per unit of carbc and hydrogen. All the heat evolved by the combustion of th hydrogen, and far more, is, however, absorbed in the act of expe ling the volatile portions of the coal. Under the classified heac of appropriation there is 27,611 calories taken up by the evapora tion of water in the coal and ore, and by the gasification of th hydrocarbons; and of this only 394 calories were absorbed i evaporating the water in the ore.

The comparatively low temperature of the escaping gases– 190° C. (374° F.)—may be taken as an indication of the larg absorption of heat in the upper region of the furnace. In th furnace using coke the temperature of its escaping gases, instea of that just indicated, was as high as 332° C. (630° F.)

Mention was made in an earlier page of this paper of the sup posed necessity which exists of maintaining a certain excess of th reducing gases in the upper region of the blast furnace. Th smallest extent to which this excess is practicable in smelting cla ironstone I have considered to be arrived at when one-third of th carbonic oxide has been converted, by the act of reduction, int carbonic acid. As there is no alteration of volume by th change of composition, the ratio of the two gases is one volume c the latter to two of the former, which means one part by weigh of the carbon as carbonic acid to two as carbonic oxide. arrived at this conclusion by finding that when calcined Clevelan ore was exposed for many hours to the escaping gases just as the left an 80-feet furnace, little or no reduction was effected.

In the case of the furnace using raw coal, these limits are far from being reached; for in its escaping gases the proportion was 4·62 volumes of carbonic oxide to 1 of carbonic acid; or, including the hydrogen and hydrocarbons (also powerful reducing agents), the ratio was 6·22 volumes to 1 volume of carbonic acid.

There are, however, other considerations connected with the action of the blast furnace, which may intervene long before the point of saturation with oxygen is reached, viz., the need for heat in the hearth itself for the fusion of the slag and iron, and such portion of the work as is delayed until that point is reached.

Of the carbon introduced into the furnace, it may be assumed that none of that contained in the hydro-carbons reaches the neighbourhood of the tuyeres. Hydrogen, however, the result of the decomposition of atmospheric moisture, is always present in the gases in that region, whether the furnace is using coke or raw coal. A specimen of this gas from the Scotch furnace using the splint coal we are considering had the following volumetric composition:—

Carbonic acid.	Carbonic oxide.	Hydrogen.	Nitrogen.		
1·40	32·96	2·60	63·04	=	100

With regard to the behaviour of the hydrogen itself, the extent to which this element has been introduced into the furnace per 20 units of iron is thus computed:—

	Weight, Units. Hydrogen.
Hydrogen contained in water of coal, viz., that in 42·39 units of coal, at the rate of 11·62 per cent. = 4·92 water, equal to	·55
Hydrogen existing as such in coal = 100 : 4·34 : : 42·39 :	1·84
Assumed weight of hydrogen due to atmospheric moisture	·08
,, ,, water in ore	·08
	2·55
Hydrogen contained in the gases in various forms, as per analysis . .	2·86
Difference (experimental error)	·31

The simplest way to compute the quantity of carbon arriving at the tuyeres is to consider the quantity of carbonic acid which ought to be in the escaping gases, and compare it with what is actually there. The deficiency must have disappeared by having dissolved so much carbon and become carbonic oxide.

In the case of the coke-fed furnace already referred to in the present communication, it is estimated that the carbon as carbonic

acid which ought to be found in the gases per 20 units of pig iron is as follows:—

	Units.	Units.
Due to the reduction of oxide of iron	6·58	
Due from decomposition of limestone	1·64	
		8·22
There was actually found in the gases (carbon as carbonic acid)		6·52
Deficiency (carbon as carbonic acid)		1·70
The fixed carbon in the coke per 20 units of iron was		20·40
Deduct that carried off by carbonic acid being resolved into carbonic oxide		1·70
Solid carbon in hearth		18·70

In the case of the Scotch furnace, using raw coal, we have the following numbers:—

	Units.	Units.
Carbon as carbonic acid, due to reduction of oxide of iron	6·58	
,, ,, from decomposition of limestone	1·31	
		7·89
There was actually found of carbon, as carbonic acid in gases		4·43
Deficiency (carbon as carbonic acid)		3·46
The fixed carbon in the coal per 20 units of iron was		22·65
Deduct that carried off by carbonic acid		3·46
Total carbon in hearth		19·19

It will thus be seen that there is no great difference (less than half a unit) in the two examples as to the quantity of carbon which actually reaches the tuyeres for fusing the iron and slag; and the difference may easily be due to the different conditions attending the operations.

Now why, it may be asked, should there be so much larger a disappearance of carbonic acid in the Scotch furnace than is observed in the English one? It should be observed that the latter had a height of 80 feet, while the former, which was 74 feet high, was found difficult to manage if filled to a greater extent than 85 per cent. of its working capacity. This difficulty arose from the contents hanging, no doubt owing to agglomeration set up by the coking of the raw coal.

One of the sources of economy of a lofty furnace is the increased period of time during which the ore is exposed to the reducing agency of carbonic oxide, at a temperature below that which suffices to have carbonic acid decomposed by carbon. Such,

I apprehend, is the cause of the disappearance of carbonic acid in the older furnaces used in Cleveland. Thus, while in one of 80 feet in height, we may have 6·52 units of carbon per 20 units of iron, as carbonic acid in a furnace of 48 feet there would be only 5·47 units.

Such may have been the cause of the loss of carbonic acid in the Scotch furnace using raw coal; but I think it highly probable that its disappearance may be partly due to the presence of the hydrogen emitted by the coal. In justification of this supposition I venture to quote certain experiments undertaken with a view to throw some light on the question before us.

One hundred parts of limestone, containing 43·61 per cent. of carbonic acid, were placed in a heated tube, and over it, during 30 minutes, a current of hydrogen was passed. At a temperature of bright redness about one-half the carbonic acid was resolved into carbonic oxide. The oxygen separated combined with the hydrogen, and the resulting water was found to correspond with the oxygen lost by the acid.

This reaction, however, is not one which would account directly for a disappearance of carbon at the tuyeres, but the watery vapours generated might react on the fuel, carrying off carbon, and again setting the hydrogen free. The main question, however, is to determine, as nearly as we can, the weight of carbon actually present in the gases at the tuyeres. There are certain disturbing causes, which time prevents my entering upon at present, but which render this ascertainment one of some difficulty. An analysis was made of the gases of the Scotch furnace with the following results:—100 volumes contained 1·40 of carbonic acid, 32·96 of carbonic oxide, 2·60 of hydrogen, and 63·04 of nitrogen.

Adopting the nitrogen as the basis of computation—*i.e.*, 89·77 units by weight of this element as present for each 20 units of iron—the carbon present works out to 20·64 units for this quantity of iron, instead of 19·19, as computed in the previous page.

As having a direct bearing on the question before us, let us assume (which we are safe in doing) that the combustion of the hydrogen and hydrocarbons contained in the Scotch splint coal would suffice for their own expulsion, and that of the oxygen and water, without any loss of the fixed carbon. According to the analysis, we should have from 100 parts of the splint coal, omit-

ting the sulphur, 58·83 of coke (53·41 fixed carbon, 5·42 ash), of which 100 parts would contain 91·63 of carbon, ·50 water, and 7·87 of ash. The quantity of heat required to smelt the iron made in the Scotch furnace, using the splint coal as coke, instead of raw coal, may be thus estimated:—

		Calories.	
Class I.	Fusion of slag (same as formerly given)	10,054	
	Decomposition of water in blast (taken as before)	3,162	
	Expulsion of carbonic acid in minerals	4,044	
	Decomposition of carbonic acid in minerals	4,192	
	Evaporation of water in ore and coke	550	
			22,002
Class II.	Reduction, &c., same as in preceding statement		52,561
Class III.	Carried off in escaping gases, considered as having a temperature of about 450° C. (842° F.), say		9,000
			83,563

The heat evolved by burning 1 part of carbon to carbonic acid and 2·28 to carbonic oxide, with air heated to 427° C. (800° F.), is as follows:—

	Calories.
1·00 Carbon to carbonic acid × 8000 =	8,000
2·28 do. carbonic oxide × 2400 =	5,472
3·28	13,472
Hence one unit of carbon gives $\frac{13,472}{3·28}$ =	4,107
Heat in blast, estimated per unit of carbon	480
Total heat evolved by each unit of carbon	4.587

Now the total heat required for the process, when using coked coal, is 83,563:—

Hence $\frac{83,568}{4,587}$ =	18·22 units of carbon per 20 units of iron
Add to this the carbon found in 20 units of the iron	·70
Total carbon per 20 units of iron	18·92

These 18·92 units are equal to 20·65 units of coke, containing 91·63 per cent. of carbon; but the coal actually used in the furnace (42·39 units per 20 units of iron) contained 22·65 units of fixed carbon, and was in consequence equal to 24·70 units of coke having the composition supposed.

According to this view of the process there is a difference of 3·73 units of carbon (22·65 − 18·92), when using coal in the

blast furnace in its raw state. Although it must be remembered that the chief source of the loss arises from the lower quantity of carbonic acid found in the gases at the Scotch works, it having been found impracticable to employ furnaces sufficiently high to ensure the same degree of saturation with oxygen as when coke is the fuel employed, this higher requirement of fixed carbon becomes still more striking—from a theoretical point of view—in comparison with that when smelting the much poorer ores of the Cleveland district. From the comparative statement on p. 10, it appears that No. 3 Cleveland iron requires 2·25 cwts. less fixed carbon than Scotch No. 1, which figure may be reduced to 1·15 cwts. for the same quality of pig in both cases. The heat requirement, so far as it depends on the richness of the ore and the nature of its earthy admixtures, is that for the fusion of the slag and the expulsion and decomposition of the carbonic acid of the minerals, and under these heads we find (see p. 11) an advantage of 8714 cals. on the side of the Scotch furnace. Nearly 2 cwts. of pure carbon would in the blast furnace be needed for the generation of this heat; the difference in the utilisation of the fixed carbon would so be raised to 3·25 cwts., to the disadvantage of the coal furnace, notwithstanding the additional heat derived from the oxidation of ·55 cwts. of hydrogen.

Let us now extend our comparison to the weight of RAW COAL actually consumed per ton of iron in either of the two modifications of smelting. The process of coking is accompanied by a certain waste, which, in the making of by far the largest quantity of coke used in Cleveland, amounts to the high figure of about 10 per cent. of the fixed carbon of the coal; while the fixed residue obtainable from good Durham coal is more than 75 per cent., the yield of coke averages only 65 per cent. We will assume a consumption of 23 cwts. of coke per ton of No. 1 Cleveland iron:—

	Coal required per Ton of Pig Iron.		Fixed Carbon in Coal used per Ton of Pig.
Cleveland furnace, coal used for 23 cwts. of coke	35·38 cwts.		25·11 cwts.
Scotch furnace, coal used in the raw state	42·31 ,,		22·60
Difference, . . More in Scotland,	6·93 cwts.	Less in Scotland,	2·51 cwts.

Remembering that the actual requirement of the Scotch fur-

nace, in so far as the ore is concerned, is about 2 cwts. of fixed carbon less than that of the Cleveland furnace, we arrive at ·51 cwts., equivalent to little more than 2 per cent., as the amount of the greater economy of the Scotch furnace as regards the consumption of fixed carbon.

This result being obtained by a comparison of two essentially different varieties of coal, it will be interesting to see how far it may or may not be corroborated by comparing the working of a Cleveland furnace using South Durham coke with that of another supposed to use the same South Durham coal in its raw state, the actual carrying out of the experiment being, as is well known, impossible owing to the nature of the coal.

The composition of this fuel may be represented by the following average of analyses of some of the most important seams of the district:—

Fixed carbon	70·32
Ash and sulphur	5·00
Moisture	1·00
Volatile above 212° F.	23·68
	100·00

In estimating the quantity of such a coal, which in the blast furnace would have the same value as a unit of coke, we have to take account of the heat needed to expel its volatile matter and the quantity of carbon capable of yielding this heat. On deducting this amount from that of the total fixed carbon of the coal, we obtain that portion of it which can replace its own weight of coke carbon:—

	Calories.
Heat required to expel 1·00 per cent. water	540
Heat required to expel 23·68 per cent. matter volatile at a higher temperature (23·68 × 2000)	47,360
Total	47,900

These 47,900 calories have to be supplied by the combustion of carbon within the blast furnace where a unit gives only 4000 calories and will appropriate $\frac{47900}{4000} = 11·97$ carbon, so that we have per 100 coal only $(70·32 - 11·97) = 58·25$ per cent., which in the blast furnace are equivalent to coke carbon.

If now 23 cwts. of coke, containing 92 per cent. or 21·16 cwts. of carbon, are needed to make a ton of iron, the weight of coal required to replace it will be $(58·25 : 100 :: 21·16) = 36·32$ cwts.

Putting the two cases side by side we have :—

Required per Ton of Pig Iron.	For Furnace using Durham Coke.	For Furnace supposed to use Durham Coal.	Difference in favour of Coke Furnace.
	Cwts.	Cwts.	
Raw coal	35·38	36·32	·94
Fixed carbon used to expel volatile matter — in coke oven	3·72	...	...
Fixed carbon used to expel volatile matter — in blast furnace	...	4·38	...
Fixed carbon used to smelt the ore	21·16	21·16	nil
Total fixed carbon	24·88	25·54	·66
Ash and sulphur	1·84	1·90	...
Volatile matter	8·66	8·88	...
	35·38	36·32	·94

In this case a small advantage is found on the side of the coke furnace, about equal to that found in the comparison of the two different varieties of fuel on the side of the coal furnace. It seems that with the mode of coking at present most general in this country it is practically indifferent, as far as consumption of coal is concerned, whether it is used in the form of coke or in its raw condition.

While the computation just made deals with the question from a purely heat-evolving point of view, it is the commercial aspect of the two modes which must determine the selection made by the ironmaster.

In the blast furnace, when raw coal * is used, a loss of fixed carbon has been shown to ensue by the solvent action on this substance exercised by carbonic acid. In the ordinary coking oven a similar waste takes place from another cause, viz., the unavoidable presence of atmospheric air in the oven itself. This takes place to the extent of about 10 per cent. of the fixed carbon in the coal; which loss represents on each ton of iron almost exactly that incurred in the blast furnaces when employing the coal in the raw state. This, of course, only adds to the greater economy stated to be derived from not having to make use of the fuel in the form of coke.

There is a still further circumstance in favour of employing

* It is assumed that coal used in the raw state is suitable for the manufacture of coke, which is not generally the case. This, however, does not affect the main object of the present paper.

raw coal in smelting iron. We have seen that whether coked or raw, in a heat-giving point of view, there is not much to choose between the two; that while about 4 cwts. of coal per ton of iron are wasted by inferior oxidation in the furnace, the same quantity is lost in the coke oven. In the former case, however, we have, in addition to the inflammable carbonic oxide of the escaping gases, about 7 cwts. of combustible gases which are useful for other purposes; whereas in the coke ovens but a very small percentage of these remains over, after satisfying the requirements of the process of coking itself.

Any comparison, however slight, between the use of raw coal and coke in the blast furnace, would be very imperfect unless some notice were taken of the recent experience in condensing the tar and ammonia given off by coal, whether it is distilled in the coke oven or in the iron furnace.

There being few varieties of coal which can be used coked or raw indifferently in smelting iron, it is almost useless to compare the conduct of the same coal under the two named conditions. Under these circumstances, a comparison will be attempted by considering the elements of calculation as they present themselves to us in actual experience. For this purpose I will select the coking coal of South Durham, and contrast it as a source of ammonia and tar with the coal used raw in the Scotch furnaces.

In such coke ovens as are employed for the purpose in question there is practically no waste of fixed carbon, the distillation being performed in a closed retort of fire-brick. If we assume that $22\frac{1}{2}$ cwts. of coke are consumed per ton of iron, we have, according to the analysis of South Durham coal formerly given, a trifle under 30 cwts. of raw coal required to furnish the coke for each such ton of metal. Estimated from the figures in the analysis just referred to, for each ton of iron made the coke ovens will have to provide means for separating the tar and ammonia from about $7\frac{1}{2}$ cwts. of gaseous matter.

In the Scotch furnaces using raw coal the weight of the gases is of course very much larger, because, besides that they contain the volatile constituents of the coal, all the fixed carbon of the coal is burnt, which means a very large admixture of atmospheric nitrogen. Instead, therefore, of having $7\frac{1}{2}$ cwts. of gases to deal with in the coke oven, for each ton of iron made with the coke

produce we have almost exactly 170 cwts. In other words, and speaking roughly, instead of having 20,390 cubic feet of gas to contend with, the furnace gases emitted by a furnace using raw coal will occupy about 260,167 cubic feet, or something like 13 times the space occupied by the volatile constituents of the coal in the process of coking.*

Under such a condition of things, it is almost needless to say that the condensable products accompanying the distillation of 30 cwts. of coal in a coke oven must be more easy of collection than the same products from 42 cwts. of raw coal burnt in a blast furnace.

Assuming that the ammonia, by far the most valuable of these products, owes its origin exclusively to the nitrogen contained in the coal, the two varieties of coal we are considering, South Durham and Scotch splint, are about equal in this respect; the former containing ·91 and the latter ·94 per cent. Inasmuch, however, as fully one-third more coal is used in the Scotch furnace than in the English, we have in the former case to deal with a proportionate increase in the ammonia-generating substance, viz., nitrogen. So far, however, as my inquiries lead me to form an opinion on the subject, there is no more ammonia and tar obtained from a ton of coal distilled by Sir J. W. Pease & Co. in the Simon-Carvés oven, than is obtained by the Messrs. Baird from the coal used in the blast furnace. This would, if true, indicate that the yield of ammonia is not affected either by the increased difficulty attending its condensation as it leaves the iron furnace, or by the known action of ammonia on oxide of iron.

The sulphate of ammonia obtained in each case was about 20 lbs. per ton of coal distilled; the alkali of this was considered worth 2s. 3·84d., reckoning the sulphate as being worth £15 per ton. The tar was worth 1s. 10d., making together 4s. 1·84d. The labour and depreciation represents about 1s., leaving 3s. 1·84d., or say 3s. per ton of coal used as such.

In the analysis of the escaping gases from the Scotch furnace using splint coal, the amount of ammonia was such as to

* The volumes of the two sets of gases are calculated for a temperature of 0°C (32° Fah.) If the temperature were about 480, which is more nearly correct, the volumes just given would be nearly doubled.

represent 12·32 lbs. of this alkali per ton of iron, or 5·81 lbs. per ton of coal. This corresponds very closely with the ammonia in 20 lbs. of the sulphate, which weighs 5·15 lbs.

On the other hand, the quantity of nitrogen in the fuel employed is sufficient to generate about 27 lbs. of ammonia per ton of coal; so that 20 lbs. of sulphate of ammonia represents only about 19 per cent. of that capable of being yielded from the coal were all the nitrogen expelled. Mr. William Foster, in a paper recently read before the Institution of Civil Engineers, pointed out that the nitrogen in coal, when distilled in a close vessel, was thus disposed of:—

11 to 18 per cent. takes the form of ammonia gas or its compounds.
·2 to 1·5 per cent. ,, cyanogen.
48 to 66 per cent. remains behind in the coke.
21 to 36 per cent. is not accounted for.

These results point therefore to the possibility that the present quantity of ammonia (20 lbs. of sulphate) obtained from each ton of coal may be susceptible of a considerable increase.

Twelve or fourteen years ago I published the result of some experiments which indicated as much as 47 lbs. of ammonia being present in coke furnace gases for each ton of coke consumed. More recently the experiment was repeated; but upon this occasion there was a mere trace of this alkali.

The demand that exists for nitrogenous compounds for agricultural purposes invests the subject with an importance entirely national in its character. This will attract an increased amount of attention; but stopping short of what is possible, and having regard to what has actually been achieved, we have more than 12 million tons of coal used by our blast furnaces alone, and probably capable of yielding substances worth at present value nearly two million pounds sterling per annum.

DISCUSSION.

Mr. I. Lowthian Bell, having read his paper, added, with re-
ırd to the possible improvement mentioned therein, that he had
een favoured by Messrs. Baird with a statement which appeared
show that they were now getting from 20 to 30 lbs. of sulphate
ammonia, and from 200 to 225 lbs. of tar, equivalent to about
2 gallons per ton. According to that statement, the net value of
ıose products appeared to be nearly double that which he had
ssumed in his paper.

Mr. Markham thought the meeting was deeply indebted
Mr. Bell for having brought forward the important subject
whether coke or coal could be used in the blast furnace
ith the greatest amount of economy and success. The first
ırt of the paper alluded to coal doing a larger, or, at any rate,
ı equivalent amount of work, as compared with coke. He
uld not conceive that statement to be correct. He believed
ıat the experiment of taking the average consumption per
ain mile was comparatively worthless, because they all knew
ıat in train mileage the loads might be heavy or light, and
thought it would have been much better to have based such
ı experiment on the amount of water evaporated. All his ex-
erience and experiments had gone to show that coke, when pro-
ıced from the same fuel, gave larger heating results than raw
al of the same quality; and it was generally the practice in
erbyshire, for blast-furnace purposes, to consider one ton of coke
equivalent to two tons of coal, the best Derbyshire hard coal
ntaining about 55 per cent. of carbon. With regard to the
ıportant question of using raw coal in the blast furnace, it had
tracted great attention in Derbyshire, where coal had been ex-
usively used in many works for a great number of years. The
aveley furnaces thirty years ago were worked entirely by coke
ade from hard coal. For reasons which were stated to be
onomical, the proprietors of those works abandoned coking,
d used raw coal for smelting, and there was no doubt, from the
d records, that the substitution of coal for coke was attended

with economical results. Raw coal had been continuously used at Staveley for the last twenty-five years. Experiments had been made with coke at various times, but without economical results. The old Derbyshire furnaces were very low, and he did not apprehend the coal was much crushed in passing downwards; but now the furnaces in that locality were being made of a much larger size. He believed that with larger furnaces raw coal was used only to a moderate extent, and that coke was now the principal fuel used for smelting purposes, as coal was crushed in consequence of the greater height of the furnaces. They had for many years made very large quantities of iron with two tons of raw Derbyshire coal, but at that time the pressure of the blast was about 2½ to 3 lbs. In recent years they had increased the pressure to nearly 6 lbs., and in his judgment the result had been a very large waste of fuel. There was no doubt the production of iron was largely increased, but it had brought about the result that they were using more coal now than ever before.

The PRESIDENT—How much?

Mr. MARKHAM—I should think nearly 5 cwts. more out of 40.

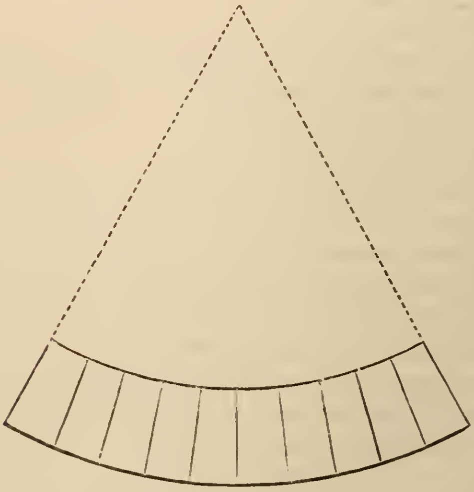
The PRESIDENT—The same ore?

Mr. MARKHAM—The same ore, the same conditions, the sam everything. When they first began to use gas, the great difficult that met them was tar. The gas tubes and the mains all becam furred up, and the gas-tar ran about, showing that they wer very near to the point Mr. Bell had discussed, viz., the collectio of tar. The tar, in passing along the tubes, collected on the sur face in large masses, which partially burnt, and had to be remove When they increased the pressure of the blast, the tar immediatel disappeared, and those practical difficulties entirely passed awa They had never seen gas-tar about the tubes since then. Bu another evil had been brought about, and they now found the ga tubes filled with dirt. No doubt the coal of Derbyshire was liab to decrepitate, and when it was thrown into a blast furnace it spl into minute particles, which were carried into the gas tube wit the dust from the iron ore. So far as he knew—and he should l

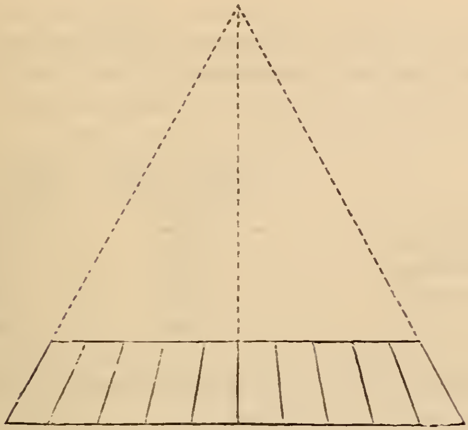
glad to hear Mr. Cochrane's views on the subject—no furnaces with closed tops had ever been successfully worked with raw coal and raw oolitic ironstone. The ironstone they used was from the oolitic deposit, and frequently contained 15 to 20 per cent. of water, and he doubted very much whether at any time the water was less than 15 per cent. even in summer. It had always appeared to him that, in throwing this ironstone on the top of their furnaces, the water was evaporated by the operation without cost for drying or calcining; but where bell-tops had been used, this 20 per cent. of water had to be forced through the stoves, which had caused a great deal of difficulty, and ultimately led to the abandonment of closed tops, which had been tried at several works. At the present time, there were furnaces with closed tops successfully working with coke and raw stone; but raw coal and raw stone, in his opinion, had never yet been worked successfully in any small furnaces with closed tops. He hoped Mr. Bell would supplement his paper by another, because he appeared to have stopped short of the economical working of coal and coke. He had always thought that in the operation of coking, as performed in the blast furnace, they got more available coke from the coal than if it had been previously coked. Mr. Cochrane had had great experience of those matters, and was well acquainted with the history of the Staffordshire furnaces, where large quantities of coal were used, and he hoped he would give some information with respect to the use of coal, because during the last few years there had been a large amount of discussion respecting coke, and but very little concerning coal.

Mr. C. COCHRANE submitted the following observations:—With reference to anthracite practice, I suppose no one is better acquainted with it than is my friend Mr. John Hartmann of Philadelphia, who recently sent a paper over to the Iron and Steel Institute, pointing out the intractable character of that fuel, and the mode of dealing with it. Since that paper was read, further experience has been gained, the result of which is to reduce the diameter of the bosh, to enlarge that of the hearth, and to compensate for reduced capacity by increasing the height to 90 feet. The object is to prevent, as far as possible, the formation of those accumulations of anthracite dust at the angles

and sides of the bosh, which so harass the managers of furnaces using anthracite fuel; and if only circumstances would permit, the wish evidently exists to get rid of the sloping side of the bosh altogether, and to make the furnace walls vertical from throat to base. In the enlargement of the hearth, the risks of the bricks floating, if vertical joints are employed, is obviously greatly increased. To meet this difficulty Mr. Hartmann has adopted a very ingenious arrangement of joints and hearth. Instead of adhering to the customary method—the old-standing practice of constructing the hearth with a flat bottom—he has boldly departed from this form, and is introducing one with a concave surface, thus—



making the hearth a fragment either of the shell of a hollow sphere, or that of a hollow cylinder, in either of which case every brick can be made exactly alike, and the stability of the hearth bottom secured against upward floating of the bricks should iron find its way beneath. A modification of the latter system was once adopted with success at Ormesby Iron Works, the radial lines being introduced, but the bricks were cut off in horizontal lines. This involved a distinct form of brick for every line of walls in the half section, thus—



Some such precaution will be absolutely necessary in future blast-furnace practice in our own country, where considerable enlargement of hearths is in contemplation; and I have much pleasure in bearing this testimony to the careful thought which Mr. Hartmann gives to the designing of the details of a blast furnace.

On the subject of the employment of coal in lieu of coke in blast furnaces, it is quite true that coal-gas does neither good nor harm in its escape at the tunnel-head of a blast furnace, whether the latter be closed or open, whether it be unburnt or burnt; and I quite concur with the author of the paper, that the low temperature of escaping gases is mainly due to absorption of heat in their evolution. In the example of the Scotch furnace using coals given in the paper, the Scotch furnace, although 75 feet high nominally, was only working at a height of 63 feet practically. Its capacity was thus greatly reduced; and like English furnaces of small capacity, the carbonic acid I believe to be removed by absorption of carbon in consequence of its evolution from reduction of the ore and disengagement from limestone being performed in the presence of red-hot coke.

The limit of 2 volumes of CO and one of CO_2, beyond which any further excess of CO_2 prevents reduction of ore, need not trouble the consideration of this matter at all, for, as a matter of fact, in furnaces of 34,000 cubic feet capacity this limit is not yet reached, although producing pig iron with about 19 cwts. of

Durham coke and Cleveland ironstone. There are still $2\frac{1}{3}$ volumes of CO to 1 of CO_2, whilst in furnaces of 20,000 cubic feet capacity this proportion rises to $3\frac{1}{3}$ volumes of CO to 1 of CO_2. To be more precise, the following are two average analyses of escaping gases :—

	17 Moisture Average. Furnace of 34,000 Capacity.	13 Moisture Average. Furnace of 20,000 Capacity.
Nitrogen	60·32	60·55
Carbonic acid	11·65	8·76
Carbonic oxide	26·92	29·55
Hydrogen	1·11	1·14
	100·00	100·00

—the larger furnace consuming about 19 cwts. of coke, the lesser about 22 cwts. per ton of pig iron.

Nor is it necessary to suggest the interposition of hydrogen in the Scotch furnace to explain the non-appearance of a larger proportion of carbonic acid than actually appears; for consider the behaviour of moisture entering the furnace with the blast. It is all decomposed, the hydrogen being set free, and carbonic oxide generated by contact with the hot coke; and as hydrogen, in precisely the same quantity, it makes its exit from the tunnel-head; so that, however we may speculate as to its changes in the upward passage, it emerges unaltered from the furnace, and must be accounted for as a heat-absorbent.

It would, therefore, appear improbable that any hydrogen introduced at the tunnel-head would escape otherwise than as hydrogen, and would simply add its volume to that due to the decomposition of moisture in the blast; and this appears to be actually the case in the Scotch furnace (see analysis, p. 19), where the escaping hydrogen amounts to 6·83 per cent. by volume of the total—a quantity five or six times as large as that usually found where coke is employed, furnishing no hydrogen.

Furthermore, in the actual experience of the use of coals at Woodside Iron Works, changes are sometimes made from coke to coals, and from coals to coke, and the practice is invariable to substitute unit for unit of fixed carbon in the two to regulate the weight of the one fuel to replace the other. It is thus, I think, rendered clear, that in the case of the Scotch furnace using raw coal, that the doubt expressed at page 25, in the words, "Such

may have been the cause of the loss of carbonic acid," may be converted into certainty by the words, "such was the cause."

In reference to the analysis (given at page 23) of gases taken from the hearth of the Scotch furnace, I think some suspicion must attach to the conditions under which the gases were collected. The analysis is as follows:—

CO_2	1·40
CO	32·96
H	2·60
N	63·44
	100·40

The hydrogen is very high—about twice as high as is usually found in a Cleveland furnace using about 22 cwts. of coke per ton of iron; whilst the source of it is the same, unless, indeed, the Scotch furnace worked so badly that green coals were carried down into the hearth, as limestone sometimes finds its way thither uncalcined, as it entered the tunnel-head, or unless there were a leaky tuyere, or steam escaping in or into the engine-house. The 1·40 carbonic acid which is shown to exist should not be there at all, unless the conditions were abnormal; for the existence of carbonic acid in the hearth of a blast furnace under normal conditions is impossible. It has been established by direct experiment, and referred to in a very able article in the periodical "Iron," that at the normal temperature of the hearth of a blast furnace carbonic acid is dissociated; and that the curious anomaly is presented that the temperature generated by carbon burnt into carbonic oxide is much higher than that obtainable by carbon burnt into carbonic acid, whilst the quantity of heat developed by the higher oxidation is, as is well known, so greatly superior to that developed by the lower oxidation. Carbonic oxide, as is seen in the household grate on a frosty night, must be cooled down before it can combine with oxygen to develop the extra units of heat furnished by the higher oxidation.

Now, may I be permitted a few words as to the oft-repeated statement about the theory of the influence of a mixture of 2 volumes of CO and 1 volume of CO_2 escaping from a blast furnace? Is this to be considered a limit of blast-furnace practice, shutting out all hope of further improvement therein? Perfectly true, as I accept it to be, that 2 volumes of CO and 1 volume of CO_2 no longer possess

any reducing power outside the furnace—they are not wanted to reduce any ironstone there—such are not the facts of the case as they are presented within the blast furnace. By increasing the capacity of the blast furnace, the reducing region has been raised into cooler zones, where the carbonic acid, once formed, is powerless for mischief, because the coke is too cool to permit its absorption. In this way, coupled with the aid of higher temperatures of blast, has it been possible to reduce the consumption of coke from what was once deemed a minimum of 22½ to 23½ cwts. down to 19 cwts. to 19½ cwts. The carbonic acid of reduction being thus harmlessly disposed of, it only remains to get rid of that evolved from limestone, the decomposition of which, at present, takes place almost entirely in a red-hot region of coke, and absorbs, of solid coke, unit for unit of the carbon contained in the CO_2 of the limestone. This will be accomplished by the caustic lime in the furnaces of large capacity.

Finally, in proof that there is something wrong, either in the conclusions of the author, or in the inferences I have drawn from his past utterances on this subject, I would appeal to the remarkable example of the Styrian furnace, with its large excess of carbonic acid escaping from the tunnel-head, and its remarkably low consumption of fuel. As bearing upon the whole subject, and what I think are currently recognised as the author's views, I hope it will not be deemed out of place to ask that, in reply, he would give the meeting some notion of his solution of this striking case, on which I ventured on a former occasion to offer a simple one.

Mr. Markham said that many years ago he had made a series of experiments, showing the evaporative power of different descriptions of coal and coke obtained from the various coal-fields in contact with the Midland Railway, and they were published at the time in the "Proceedings of the Institution of Mechanical Engineers." He had every reason to believe they were the most reliable experiments that had yet been published on the subject.

Mr. Stores Smith (Sheepbridge) said he had had a large experience in blast furnaces not far from Mr. Markham's furnaces, and he could corroborate what that gentleman had

said as to the remarkable disappearance of tar from the gas tubes by the increase of the pressure of the blast. When first they began to take off gases from their furnaces, which they did by suction, and without closed tops, they were completely stopped by the enormous accumulations of tar. They tried every way to evade it, and to a certain extent they did get rid of it. He believed Mr. Markham first suggested to him an increase of blast, which he said he had found to answer at Staveley. The pressure was accordingly largely increased, and the tar vanished. There had never been a trace of it since then. Another experience of theirs, however, had been diametrically opposite to that of Mr. Markham: their increase of pressure of blast had not been attended with an increased consumption of coal per ton of pig iron. Mr. Markham had asked him a few days ago whether his attention had been directed to this matter, and he (Mr. Stores Smith) could only then say that it was continually coming before him in a general way. At that time he knew generally that they were making iron cheaper than ever before in the total cost, and since then he had had the figures got out accurately. The following figures showed correctly the amount of coal used half-yearly in 1880–81, before the pressure of blast had been increased, and in 1882–83, after it had been increased, per ton of pig iron produced:—To June 1880, 2 tons 4 cwts. 3 qrs.; to December, 2 tons 5 cwts. 3 qrs.; to June 1881, 2 tons 3 cwts. 3 qrs.; to December, 2 tons 5 cwts. 3 qrs.; to June 1882, 1 ton 19 cwts. 3 qrs.; to December, 2 tons 2 qrs.; to June 1883, 2 tons 2 qrs.; to December, 2 tons 2 qrs. There was only one point of difference between the constituents of Mr. Markham's experiments and his own. Simultaneously with increasing the blast, he (Mr. Stores Smith) greatly increased their heats. Two years ago they were working at an average heat of 600°; at the present moment they were working at an average heat of 900°, which was a very great difference; and the result had been certainly a saving of 5 cwts. of fuel per ton of iron made. Mr. Markham's experience of increasing the blast alone had been an increase in the consumption of coal. It was only fair to state that he (Mr. Stores Smith) also used coke at his furnaces, and Mr. Markham did not. They used $\frac{1}{8}$th coke to $\frac{7}{8}$ths raw coal, and the figures he had given had been reduced to the coal calcu-

lation from a long experience of what they found to be the equivalent of coke to coal. The experience of twelve years, accurately taken out, had shown that 8 cwts. of coal gave $5\frac{1}{2}$ cwts. of coke. The $\frac{1}{8}$th of coke had been added to the total weight of coal used on that basis. For all practical purposes the paper was an exceedingly valuable one, but each district could only work according to its conditions ; and before they could say which was the cheaper to use—coke or coal—they must know the relative costs of coke and coal in the districts in which they lived. In Derbyshire they had the top-hard coal, and they had it cheap. It was worth, say, 6s. per ton of 21 cwts. at the ovens, and it would not coke. They had also one of the finest bituminous Silkstone coals, which made the finest coke in England. It was valuable for the best processes of steel-melting, and it went to Birmingham and Sheffield for the most particular purposes. It was singularly free from sulphur, and had but a small proportion of ash. The few months' average price of this coke was very nearly 12s. for 20 cwts. at the ovens, and there could be no doubt that they would be simply lunatics to put that coke into blast furnaces in place of the coal that was at hand.

Sir James Ramsden asked if there had been an increased make?

Mr. Stores Smith—Oh yes, considerably. About ten years ago the total make of five furnaces did not exceed 36,000 tons per annum ; now the make was over 1000 tons a week, out of the same five furnaces, and that was got as regularly as possible. The pressure of the blast was never less than from 4 to $4\frac{1}{4}$—they seldom got to $4\frac{1}{2}$ lbs.—and formerly it was about 3 lbs.

Mr. Markham said Mr. Cochrane had stated that it did not matter whether a furnace was closed or not ; but his experience did not enable him to concur in that view, as the experiments they had made clearly proved that when a large amount of gas was drawn from the top of the furnace, the production of iron was diminished, and the furnace would not drive so fast ; but when there was a large flame on the top of their furnaces they drove better and made more iron. He attributed this to the fact that when the gas was drawn out there was not sufficient heat to burn

he tar, which probably deposited upon the mill and ironstone, nd coated it over with a thin film, which was not burnt off ntil the material had descended a long way in the furnace. He wished it to be clearly understood that those remarks applied o low furnaces with raw coal. They had no back pressure in heir furnaces, as the gas was drawn off through the tubes by uction.

Mr. COCHRANE said that reference had been made by Mr. Markam to the use of closed tops, but he believed that he had practially answered that point. He found no difference in the conumption of coal or coke with a closed-top furnace as compared rith an open-topped furnace, provided the effective height of the aaterials was maintained in the former. He had no doubt that Ir. Markham referred to the former failure of closed tops with ow furnaces. So much was it thought to be a failure in its pplication in Staffordshire, that at Woodside Iron Works, as some riends passed by in the train and saw its application in progress here, they called it "Cochrane's folly," and said, "He is putting closed bell on to a Staffordshire furnace, and it will be sure o fail." The cause of previous failure was that in a furnace not aore than 48 feet high, 7 or 8 feet were sacrificed in putting on bell. A great deal of coke was thus lost in consequence of educed capacity of furnace, and the circumstance was attributed o a wrong cause. The furnaces at Woodside were raised to a orresponding height to that which would be cut off by the pplication of the bell. That was the whole secret of the matter o which Mr. Markham had referred. With regard to the disppearance of the tar, their experience was the same as that aentioned by the author, and they had recourse to all sorts of levices, when the bell was first applied, to dispose and get rid of he tar. On application of extra blast to the furnace, the tar lisappeared. The extra blast gave a little extra temperature to he escaping gases, and kept the tar in a state of gas. The gases eing a few degrees warmer, prevented the tar from condensing ntil they wished to condense it at their own convenience. Not hat they had got rid of it altogether, but they had it under their ontrol. He might state that at Woodside Iron Works they used ialf coal and half coke, weight for weight.

Mr. Robert Heath said that when they began taking off gas they had some difficulty with the tar; but all their main lines were lined with bricks, and that prevented the condensation of the tar, so that they had no further trouble with it. With regard to the taking-off furnace referred to by Mr. Markham, they had tried one some years ago, taking off the gas only on one side with one down tube; but they could not manage it, because they had a considerable pressure on the furnace. In the furnace that he was now working, he had a tube both back and front, consequently he had a double capacity for taking off the gas as compared with the method adopted by most people. Since they had adopted that plan, they had had no trouble.

Mr. E. P. Martin asked if the back pressure was not very great in that case? At Dowlais they used raw coal with a burden of cinder and hematite ore only, and found no difficulty in using a bell. At first the gas mains were too small to take off the gases, and until they were enlarged the back pressure interfered with the smoke of the furnaces.

Mr. Robert Heath said that his firm had made iron with raw coal for forty years. They had not found it quite so easy when they had a higher temperature of blast; still, they used the higher temperature and the raw coal. They also used closed tops, and they had sufficient steam from them not only to work colliery engines, in addition to blast-furnace engines, but they had a good deal also available for manufacturing iron. They used nothing but coal, and all the ironstone was calcined.

Mr. Horton said he had used very successfully raw coal of a very tender quality, and one that was considered to be rather inferior for furnace purposes, in furnaces with which he was connected. Those furnaces were working with something like 38 cwts. of raw coal, and were turning out 320 tons of iron a week. He had other furnaces that were making excellent mill iron with 17½ cwts. of coke, the coke being made from ground and washed coal.

Mr. G. J. Snelus said that the subject on which Mr. Bell had

spoken was one in which he had taken considerable interest for some time, and he thought that he could perhaps throw a little light upon one question which was involved in some obscurity by an experiment which he had been making during the last twelve months with one of their own furnaces in West Cumberland. He believed that the reason why the limit fixed by Mr. Bell of two volumes of carbonic oxide to one of carbonic acid was approximated in the Cleveland district was that he was there using a calcined stone with coke, and therefore he had a higher temperature at the top of the furnace, and the conditions were more favourable for the reducing action of the carbonic oxide to go on. They had found in the West Cumberland district that they could not reach that figure; in fact, they rather approximated to the figures which Mr. Bell had given of raw coal in the Scotch district. He (Mr. Snelus) had been making daily analyses of the gas in one furnace during the past twelve months, and he could not get anything like the proportions of carbonic acid that Mr. Bell had indicated. That had puzzled him for a long time, but he had now come to the conclusion that the reason was that they were using iron ore which contained a good deal of moisture; they were not using calcined stone, but the raw stone of the district; and although it did not contain anything like the moisture which Mr. Markham referred to as being in the Northamptonshire ore, viz., 20 per cent., it contained a large quantity, from 12 to 15 per cent. He believed it was the lowering of the temperature at the top of the blast furnace that prevented their usefully employing the carbonic oxide. They therefore found that they were not able to decrease the proportion beyond about 7 or 8 per cent. of carbonic acid to form 28 to 29 per cent. of carbonic oxide by volume, being, in fact, very nearly the figures given by Mr. Bell for the Scotch furnaces. He believed that the Scotch furnaces using raw coal were in the same position, even though they might be using calcined stone, the difference being that where the coal was used the temperature was lowered by having to volatilise the volatile products of the coal. He believed they would improve the working of their furnaces very much if they were to endeavour to avoid all extraneous uses of the fuel—that was, if they could calcine their ores, if they calcined the limestone, and in every case, as far as possible,

limited the work they wanted the fuel to do to the reduction and melting—not volatilisation—of the products of the coal, or the evaporation of the water. But, unfortunately, there came the question of cost. Mr. Cochrane was right in saying that they would save a good deal if they could put caustic lime into their tall furnaces; but they all knew the difficulty of retaining caustic lime as caustic lime for any length of time, and the impracticability of calcining stone close to their furnaces. On the other hand, he thought that the furnaces that were using Lincolnshire and Northamptonshire ores ought to reap a great improvement by calcining the stone outside. Of course he would be met by the answer, "It is all very well to calcine it outside, but it crumbles, and there is a loss." He had gone into the question carefully, and he was convinced that, even apart from the loss of the ore, which they would undoubtedly have to get rid of, there would be a considerable saving by calcining the Northamptonshire stone, and not putting it into the furnace in a raw state. If that were done, it would obviate the difficulty which Mr. Markham had suggested as to the use of a closed top. A great deal depended upon limiting the work done in blast furnaces to reduction and melting.

Mr. E. Williams did not think it mattered whether the throat of a furnace in work was open or closed, so long as free egress was allowed the gases. If there was any retardation, it must very prejudicially affect the work of the furnace; but supposing the outlets sufficient, it did not seem to matter at all where the ultimate products of combustion were discharged. He had known furnaces work very well year after year with raw coal and ore, with about 10 per cent. of water upon the average. He had also known furnaces where nothing but Northamptonshire ore was used, and he failed to see how the working of the furnace would be prejudicially interfered with by closing the throat, the means of egress for the gases being ample. He had used lime, very well burnt, in furnaces of all heights, from 90 feet to 50 feet, but he was sorry to say without success. After trying it for years, there was no advantage that he could discover, and he had gone back to limestone. He had had no experience of furnaces making iron from Cleveland stone with 19 cwts. of coke, although no one

appreciated the great advantage of economy in that direction more than he did. So far as he knew, the consumption of coke to the ton of Cleveland iron was nearer 23 than 19 cwts. all over the district, and that, too, after great attention had been given to the subject. He did not believe that increasing the internal capacity of the furnace necessarily produced economy; indeed, it might produce exactly the reverse. If they started with a furnace 45 feet high, and instead of having it 16 or 17 feet at the boshes (which was large enough for that height), they doubled its internal capacity by simply enlarging it and making it broader everywhere, there was no economy, but the reverse. Increase the capacity of the furnace by adding to its height, and fuel would be economised. He did not think enlarging in any other direction would be useful, but in many cases it would be actually prejudicial. Many years ago, when he was at Dowlais, Mr. Menelaus put on a furnace the very cream of the raw coal that could be got in order to see what was possible, and the consumption per ton of pig iron was very low—but little above the average quantity of coke.

Mr. Bell asked what was the composition of the coal?

Mr. Williams said it was the very best of the upper four-feet seam.

The President—Was it a bituminous coal?

Mr. Williams—Not at all. It seemed to him that whether raw coal or coke should be used depended on two circumstances. The first was whether raw coal was suitable at all. It was no use talking of what could be done theoretically with coal in the blast furnaces of the Cleveland district, because the local coal could not be used for mechanical reasons; it would gob up the blast furnaces; but there were districts where raw coal could be used. The best of the steam-coal in South Wales could be used without difficulty, and it was only a question whether, all things considered, it was cheaper to use coal or coke. At present, good steam-coal was at a high price, while the price of coke was comparatively low; and any one who chose to adopt coal instead of

coke would find that though his furnace worked well enough, his cost would go up abominably. At Dowlais several years ago they had great pressure against the bells of the furnaces using raw coal, and Mr. Menelaus put up a large fan, 30 feet in diameter, to exhaust the gases from the furnace throats. By that means the pressure on the bells was got rid of, but they were overwhelmed with tar. The culverts and tubes were choked with it, and they had to stop the fan, which had taken off the gases at too low a temperature. A little higher temperature got rid of the tar—that was to say, wasted it—and they had to go on much in the old way. He held it to be heresy to suppose that the closing of the throat of a blast furnace need interfere with the work of that furnace, however it was charged.

Mr. J. E. Stead said that reference had been made to the very small amount of carbonic oxide escaping from coke ovens. He had recently investigated that matter, and had found that there was really a very small amount of carbonic oxide present. He had had an idea that it might be a rather good thing to exhaust the gases from the top of a coke oven, and extract the ammonia and any other valuable matter that happened to be there. With an ordinary beehive oven, he thought it would be a cheaper mode than exhausting from the bottom. In doing that, he found that the gases were poor in carbonic oxide, and contained no ammonia at all. Reference had been made to a remark of Mr. William Foster, with regard to the mode in which nitrogen in coal was disposed of in coking. He thought that the analysis given might be explained by the peculiar way in which the coal had been coked. If coal was coked at a low temperature, in a close vessel in the laboratory, in all probability 40 or 48 per cent. of nitrogen might remain behind, but as a matter of fact, when it was coked in a beehive oven, nothing like that proportion was found in the coke.

Mr. William Foster said he had no doubt that the remark just made was perfectly true in the main, but, unfortunately, he had not had the opportunity of pursuing the matter fully. When he read his paper a few weeks ago, Mr. Lowthian Bell criticised it in a manner that was very gratifying to him, and he said he saw the possibility of the increase in the yield of ammonia; but that

was only one of the points raised in the paper. There was a great deal made at the present time of the possibility of the yield of ammonia. Twenty pounds of sulphate per ton of coal, whether carbonised in a gas retort or a Simon-Carvés oven, or in any other way, was, he believed, about the general yield, but there was no great difficulty in increasing it to 30 lbs. by special treatment. The possibilities of ammonia production from coal, however, were far beyond that figure. It was scarcely possible to deal with the many points which he had come across during his three years' work, but the chief feature of it related to the retention of a great portion of nitrogen by the coke. He attached great importance to that point. Those who were familiar with the elements of chemistry knew that nitrogen was spoken of as a negative element, an element not characterised by any particular attributes. When, therefore, coal containing a given quantity of nitrogen was carbonised or heated in a close retort, and when it was found that the nitrogen came next to the carbon in its power of resisting the tendency to pass off in gaseous forms, the observation was an important one. Only two or three years ago, Professors Leiving and Dewar, at Cambridge, had made some extraordinary observations on the production of cyanogen in the electric arc. Those were theoretical points; but they had a bearing on the retention of nitrogen by coke and its being turned into ammonia by the subsequent action of steam. The circumstance of their being able to get so large an amount of ammonia from the coke after it had been removed from a gas retort showed what might go on in the ordinary blast-furnace where raw coal was used. Mr. Bell had pointed out that the notion that he (Mr. Foster) had advanced was rather in opposition to the experiments of Professors Bunsen and Playfair, undertaken forty years ago. His aim, however, had been to show the possibility of an enormous increase in the yield of ammonia.

Mr. FISHER SMITH said he did not think that enough had been said as to the bearing of the size of the furnace on the quality of the coal. He did not think that weak coal would do with a tall furnace, but with a strong coal a high furnace would very much improve the yield. The height of a furnace had in all cases, he believed, a great deal to do with the quality of the coal used.

Mr. W. S. SUTHERLAND said that the velocity at which the gas travelled had a great deal to do with getting rid of the tar. They had found that a higher pressure put upon a set of gas-producers, so as to increase the velocity, carried away the whole of the tar, and they had employed special means to get the tar deposited.

Mr. COWAN said that the tar question was one that had lately given them a good deal of trouble at the works with which he was connected, namely, Carron Works. The furnaces were closed in the usual way by a bell and cone, thus reducing the working height to about 44 feet. When the gases were first taken off, they deposited no tar whatever in the tubes, the length of the tubes in use being comparatively short and all lined, but when the tubes were extended a distance of 2500 feet, there was abundance of tar deposited in those portions of the tubes most distant from the furnaces. The inference that he drew was that it was simply a question of a little more or less heat in the escaping gas. If the gases at the top of the furnace were drawn off at a higher temperature, there was no tar until they were cooled down. Those tubes at considerable distances from the furnaces acted as condensers, being unlined, and the tar was collected therefrom into a well.

A remark had been made with regard to the increase in the consumption of coal if the pressure of the blast was increased He had no doubt that that would be the case if the blast-heating surfaces were not increased in proportion. If they increased the heating surface, and sent the blast into the furnaces at the same temperature as it had when there was a lower pressure, there would be a saving of fuel. In the low furnaces to which he had alluded, working at a height of 44 feet, the consumption of raw coal was at one time as low as 40 cwt. The coal used was of two qualities: one was good splint, containing very little impurities, and the other an inferior coal, containing about 11 per cent of ash. In his own experience he had found it desirable to use a small portion of coke along with the coal, say about 5 cwts. per ton of iron. By doing that, and making various improvements in the plant, he had obtained an increased yield from 180 tons with fourteen casts per week, to 200 tons with thirteen casts. They

had to stop one cast on Sunday for the purpose of cleaning out the tubes.

A good deal had been said as to the value of the tar. As to this there was still some difference in opinion. Gas-tar, it was well known, contained many valuable constituents, from some of which colours were obtained. In blast-furnace tar these were said to be absent, hence the tar had a low value. It was chiefly valuable for its pitch. No one had yet been found who would take away the tar from Carron Works for the lifting. A little more light was required on this subject.

[Mr. E. A. Cowper states, through the Secretary, that it was impossible for him to be present at the interesting discussion on Mr. Bell's paper. He wishes it to be known, however, that a ton of forge iron is now being made with 29 cwts. of coal, and a ton of No. 1 iron with 30½ cwts. of coal in the furnaces of the Stafford Iron and Coal Company, which are fitted with Cowper stoves.]

The President said that Mr. Bell's interesting paper had elicited one or two points in the course of the discussion which might be worthy of notice apart from any reply which he might offer. One was the statement made by Mr. Cochrane in regard to the very important improvements in the anthracite furnaces of Pennsylvania. Mr. Bell had mentioned that 40 or 45 per cent. of the iron of the United States was still produced by anthracite coal, and that the total amount of iron so produced exceeded 2,000,000 tons. He (the President), however, believed that until lately the proportion of iron made with anthracite coal in the United States had been constantly diminishing, that it had been found more advantageous to use the bituminous coal of Western Pennsylvania in preference to the anthracite coal of the eastern portion of that State. If that should cease to be the case, it might afford some hope that they might be able to utilise the enormous deposits of anthracite coal existing in the western portion of the Principality of Wales, which had hitherto, he believed, been utilised chiefly for some such trifling objects as malting, &c. In that way their resources for the production of iron would be very much increased. Although it might not be of very great

importance at the present moment, the time might come when it would be of importance to the country to be able to have recourse to anthracite coal. With regard to what had been said as to the use of calcined lime in blast furnaces in the Cleveland district, he was almost afraid of saying a word to open again the interminable discussions as to the working of the Cleveland blast furnace. He might mention, however, that at his own works he had repeatedly tried burnt lime, and had never found that the results had justified his doing so. He might also state that, although they had blast furnaces of a cubical capacity approaching those of Mr. Charles Cochrane, a capacity of from 28,000 to 30,000 feet, and 84 feet in height, they had not been able to attain the brilliant results which he believed had alone been achieved by Mr. Charles Cochrane. The chief merit of Mr. Bell's paper was that it had opened up, for the first time within the walls of the Institute, the question of the use of raw coal in the blast furnace. Although it contained very important and elaborate theoretical calculations, which, no doubt, would be of great value as a kind of loadstar to any future discussions, it did not deal extensively with the use of raw coal in various districts, and that was a portion of the subject to which he desired to draw Mr. Bell's attention, so that, upon future occasions, they might have the benefit of his experience as to the results of the use of raw coal in other districts than the West of Scotland. He had noticed one peculiar feature in the discussion, viz., that those who had taken part in it and had had experience of raw coal, rather rejoiced in the fact of their having found means of volatilising the tar, not allowing it to appear even in the form of tar outside the blast-furnace. When they considered what Mr. Bell had stated, that the value of the tar was 1s. or more per ton of coal consumed, and that the quantity obtained was now said to be double, making the amount 2s., he thought they ought to look a little more closely after the tar in the future. It really opened out a subject which it was impossible to deal with at the end of a discussion on a paper of that kind. Mr. Bell had stated that 7 cwts. of combustible gases passed away from the blast furnaces where raw coal was used. That was an amount of fuel which ought not to be allowed to escape, and which, he thought, would not be allowed to escape much longer without being turned

to more economical use than the mere heating of stoves and boilers. Messrs. Baird and Messrs. Addie had taken the lead in the matter, and no doubt the subject was one which ought to engage the attention of the members of the Institute more generally than it had done. With regard to the cases in which coke was used, Mr. Bell had pointed out that at present in their ordinary coke ovens they were consuming 10 per cent. of carbon entirely to waste. They were admitting atmospheric air with the result of destroying 10 per cent. of the whole of the carbon in the coal, which was equal to about 16 or 17 per cent. of the quantity of coke that might otherwise be realised; and not only were they doing so, but by the same wasteful mode of producing coke they were allowing bye-products which were of great value to escape. They were allowing 1s. worth of tar per ton of coal, or 16d. or 17d. of tar per ton of coke, to escape without being utilised, and they were also losing ammonia, which was valued at 2s. per ton of coal; and they were told that there was a possibility, by appropriate methods, of multiplying that five-fold in future, so that they might have 10s. worth of ammonia from each ton of coal. In Cleveland practice they might have 16s. worth of ammonia for every ton of iron made, and from 1s. to 2s. worth of tar. So that they might have 18s. worth of products that now went to waste for every ton of iron made in the furnaces. But if they only doubled the quantity, and consequently the value of the ammonia now obtained at the coke ovens, it might become a consideration whether they ought not, instead of endeavouring to economise fuel, actually to aim at increasing the consumption of fuel in the blast furnaces as much as they possibly could. That might lead to changes in the structure of the blast furnaces which at present it was impossible to foresee. He mentioned that in order to show what a progressive craft iron and steel makers were. They were always looking forward to the future. If they were now somewhat depressed by the conditions of the trade, they had always hope in the future, and they meant to look to each other and to an Institute like their own, where they communicated to each other, freely and frankly, all the information gained by each of the members, to enable them to survive even times like the present, believing that the iron industry of the country and of the world had still prosperous days in store.

Mr. I. Lowthian Bell, in reply, said Mr. Markham had spoken in somewhat disparaging terms of his endeavour to show that 1 lb. of coal or coke *qua* calorific power meant pretty nearly the same thing. He said (and they were all ready to admit it) that differences in the weight of the loads conveyed on a railway and the question of gradients affected the consumption of fuel; but Mr. Markham had not read with his accustomed care what he (Mr. Bell) had written. If he had done so, he would have seen that the experiments with coal and coke were carried out upon the same stretches of road; hence the gradients were the same in each case, and the loads as nearly the same as possible. He did not say that each train weighed within a hundredweight or two of the train with which it was compared; but they had not only the same number of waggons, but actually the same waggons, filled in the one case as in the other. His objection, therefore, to the experiments did not hold. In spite of the length of the paper, which had been drawn out to eighteen pages, his friend had rather taunted him with not having gone far enough. His fear all along had been that he had gone very much too far, and in consequence he had curtailed everything he possibly could in reading the paper itself. Mr. Markham also said that coal was more economical when used as fuel in the blast furnace, and rather reproached him with not having said the same. So far as his power of expressing himself enabled him, he said precisely the same thing—that raw coal, when it could be used raw, was distinctly more economical in a money point of view than using coked coal. Mr. Stores Smith and Mr. Williams had pointed out that no rule, applicable to all cases, could be laid down as to the relative advantages attending the use of coke or coal. In every case, and necessarily so, the first question to be answered was, "Can the coal be used raw?" Thus it was well known that at Middlesbrough the coal of the district could not be used in its raw state, and therefore it was useless, as a mere matter of economy, to make any comparison. All that he had attempted in the paper was to expose those laws upon which the action of fuel was dependent, and every district must make its own calculation. But suppose they had a coal which could be used indifferently raw or coked, if the large coal could be separated at the collieries, and sold at a higher

price than it was worth when made into coke, the small coal could be coked and the large coal would, of course, be sold as such. With regard to the difficulty of using raw coal on account of accumulations of tar, Mr. Markham had been met by a trouble which had beset others besides himself. It seemed to him (Mr. Bell), however, there was no difficulty in ascertaining what had taken place when the pressure of the blast was increased in the manner described by Mr. Markham. A larger volume of air was driven through the furnace, and in consequence a higher temperature of the escaping gases would follow, from their being no longer retained so long among the cooler materials entering the top of the furnace. The result would be that the tarry vapours would no longer condense so easily as before, and the gases being hotter accounted for waste of fuel, noticed by Mr. Markham. He must confess that that opinion had been a little shaken, in the first instance, by what Mr. Stores Smith had told them of his having increased the pressure without an increased consumption of coal having followed; but he had explained it by saying that the temperature of his blast was increased, so that, in point of fact, he had got the extra heat, not by burning more coal, as Mr. Markham had done, but by conferring more heat on his blast. The reason of the blast in Mr. Smith's case being hotter admitted of a very easy explanation. According to the accounts given to him (Mr. Bell) from Gartsherrie, there were 224 lbs. of tar given off for every ton of coal, and using two tons of coal per ton of iron made, there would be 448 lbs. of tar. Now this tar, as they all knew, gave out a great deal of heat during its combustion. Mr. Smith treated his gases so that the whole of that tar was burnt in his stoves, and therefore he secured a large increase of temperature in his blast. With regard to closed tops not being applicable to low furnaces using raw coal, Mr. Markham made the observation perhaps in a more general sense than he intended, because he (Mr. Bell) imagined that it had reference to the Northamptonshire stone alone.

Mr. Markham said that was so.

Mr. I. L. Bell was not prepared to say there was not something

in what Mr. Markham had said on that head. In a closed-top furnace, no gas was burnt on the surface of the materials, but in one where a portion of the gases is consumed there, an opportunity was afforded of evaporating a portion of that water which was a natural constituent of ironstone used under the circumstances described by Mr. Markham. Mr. Cochrane had told them that it was impossible for hydrogen to act as a reducing agent upon the ore. He (Mr. Bell) must confess that, as a rule, he had not found that hydrogen in coke furnaces did perform any important duty in the direction just referred to. There was little or no hydrogen in the materials in a furnace using coke, and what hydrogen was found in the gases was due to the decomposition of the hygrometric moisture of the blast; and so far as he had been able to discover, any hydrogen so produced appeared at the top as hydrogen, unchanged. The quantity of moisture in the air was constantly varying, and thus it was clear that it would be impossible to ascertain precisely the condition of things obtaining at the time of making each experiment. Therefore he had always assumed an average quantity of hygrometric moisture, and he had generally found the hydrogen present corresponded pretty closely with the assumption so made. Mr. Cochrane had supposed that the Scotch experiments were not correct. Now, in order to ensure their correctness as far as possible, instead of being content with taking the gases over a few minutes, or even a quarter of an hour, he (Mr. Bell) had had the analyses made upon samples collected during two hours. His assistant in the laboratory was not only a very competent but a very careful analyst, and he had never yet found any reason to impugn his accuracy. Mr. Cochrane had denied that any hydrogen had been oxidised in the upper part of the furnace. True, it was a small quantity—·55 cwts. for each ton of iron,—but the consumption of this weight, small as it was, meant 18,000 calories or heat units, or something like 6 per cent. of the total heat given off by the coal. They had been told also that carbonic acid in the hearth of a blast furnace was another impossibility. It was not by one analysis only, but by a very numerous series, that he had proved over and over again that the presence of carbonic acid was perfectly possible. Mr. Cochrane had spoken of the heat of the lower part of the blast furnace being equal to the dissociation

of carbonic acid, with which he (Mr. Bell) was not prepared to disagree; but he thought that there were spaces where the heat being undoubtedly far below the point of dissociation, carbonic acid was to be found there. Although he (Mr. Bell) agreed with what had fallen from Mr. Cochrane in reference to the dissociation of carbonic acid at high temperatures, he did not agree that this was the cause of carbonic oxide being found in an ordinary domestic grate. The temperature under such circumstances was, he thought, far below that required for decomposing carbonic acid, and the formation of carbonic oxide there was simply due to an equivalent of red-hot carbon acting on an equivalent of carbonic acid, and so generating two equivalents of carbonic oxide.

With regard to avoiding the introduction of carbonic acid by using burnt lime, he (Mr. Bell) had tried it with some advantage in furnaces of the old type, but in the present lofty ones he had satisfied himself that there was no economy. As to the cause of that, his opinions had already been published. They consisted in supposing that the quicklime absorbed carbonic acid in the upper region, which, being carried down to the hotter zone, produced the same evil as unburnt limestone.

With reference to his (Mr. Bell's) old theory as to the relative volumes of carbonic oxide and carbonic acid in the gases of a blast furnace, Mr. Cochrane went off to Styria. Mr. Cochrane, however, ought to remember that he (Mr. Bell), in the cases referred to, invariably applied his reasoning to the ores of Cleveland, because he had ascertained, by a series of carefully conducted experiments, that different kinds of ore parted with their oxygen with different degrees of velocity or readiness. The atoms of iron in this ore were able, probably merely from mechanical structure, to keep hold of the oxygen so much more forcibly that it required a greater or a higher power than in the case of the Styrian ores to separate them. That being the case, it might well be conceived possible (he did not wish to lay it down as an absolute fact) that the combination of two volumes of carbonic oxide with one of carbonic acid might constitute an agent insufficient to reduce Cleveland stone, but sufficient to reduce others. With reference to the small quantity of charcoal used in the Styrian

furnace, he had availed himself of the opportunity afforded him in Styria, as he had done previously in Carinthia and elsewhere, to ascertain the facts connected with the use of charcoal in smelting iron; and the result was that he (Mr. Bell) prepared a paper expressly on the subject. He found that small as was the quantity of carbon used in the form of charcoal, it was perfectly easy to reconcile theory with the practice. It should not be supposed, when they were speaking of the duty performed in a blast furnace, that its amount was always of the same character. In the Cleveland stone they were using an ore containing 40 or 42 per cent. of iron, and they were using 10 or $10\frac{1}{2}$ cwts. of limestone, and thus making 26 cwts. of slag. In Styria they were using a material containing 60 per cent. of iron, and generating only about 6 cwts. of slag. It was, therefore, idle to compare, without proper allowance, the practice of Styria with that of Cleveland. It was true he was not prepared, except upon the grounds he had mentioned, to explain how it was that there was more carbonic acid in the gases of the Styrian furnace than in Cleveland; but he might say that the quantity of carbonic acid which was capable of being produced by a reduction of the ore was far below that which escaped in their own blast furnaces. The President had stated, in referring to anthracite, that in this country it was used merely for malting purposes. It had, however, been used for a long time, as it was still used, in blast furnaces; but undoubtedly it was not equal to the American anthracite for this purpose—at least, better results were obtained in the United States than with South Wales coal. With regard to the alleged falling off in America, this he apprehended was more apparent than real. As long as ore was being smelted near the great anthracite deposits, so long would they continue to use anthracite coal. If the iron trade was extended in America in districts where there was no anthracite, undoubtedly bituminous coal would then be used. With regard to the quantity of ammonia he might say, in reference to what had fallen from Mr. Foster, that it was well for ironmasters to know what the limits were to which they could carry the production of ammonia. As he had pointed out at the Institution of Civil Engineers, it did not follow that they would reach those limits, but rather that, having

ttained them, it would be useless to incur any expense in ndeavouring to go beyond them.

The PRESIDENT proposed a vote of thanks to Mr. Bell for his excellent paper, which was unanimously agreed to.

The following papers were then read :—

GAS PUDDLING AND HEATING FURNACES, WITH SPECIAL REFERENCE TO THE "CASSON-BICHEROUX" SYSTEM.

By Mr. R. SMITH-CASSON, Brierley Hill.

As the first gas-furnaces introduced into England were built in connection with Messrs. Siemens' Regenerator, the notion of a gas-furnace is usually connected with the "regenerator" arrangement. The first attempts to puddle with gas were made with the waste gases of the blast-furnace. Gas-furnaces, however, in which the fuel was systematically used in the fluid state, and in which the air for combustion was previously heated before being supplied in definite volumes to the gaseous fuel, were in practical use in Austria for many years before the appearance of the regenerative furnace.

Professor Von Tunner, as long ago as 1842, described a gas-furnace in practical use for puddling at some works in Carinthia It will have been noticed by the members who visited Styria in 1882, that very fine iron ores are there found in juxtapositio with a scanty supply of wood, peat, or inferior lignite or brow coal. It is certain that, during the last forty years, gas-furnaces without regenerators, have been in practical use, and in som works in exclusive employment, in the ironworks of Styria Carinthia, and Carniola. The application of the regenerator t gas-furnaces, while admirable in cases wherein very high tempera tures are required, is not of such value in puddling or in heatin iron or steel blooms, which can be done at comparatively lo temperatures.

I have no means at command of giving the exact date whe the first gas puddling furnaces were introduced by the late Si William Siemens; but I recollect that in 1862 he made trials a the Earl of Dudley's Round Oak Ironworks, which were nc successful. In order to ascertain the reasons why the result were not satisfactory, I wrote to Mr. Job Richards, the the

works manager, for an explanation, and in reply he has handed to me extracts from his diary, showing the daily results of the experiments, and giving it as his opinion that the failure was due to the want of efficient control over the gas and air, and, consequently, to an insufficiency of heat. In my opinion, the failure was owing to the non-application of blast to the "gas-producers," which my experience has shown to be desirable with South Staffordshire coal. Since the period above named, Messrs. Siemens have been successful in puddling with gas at several works, notably at Messrs. Nettlefolds', Wellington, Salop, and I have pleasure in presenting herewith the results obtained at the works in question (see p. 7).

The furnace known as the "Bœtius," arranged with a gas-producer in lieu of the ordinary grate, was supplied to all the puddling furnaces erected at a small works on the Thames which I visited in 1873. The works were not then in operation, but one of the proprietors informed me that they worked very satisfactorily and economically. The same system is now in operation at a glassworks at Warrington, where it is, I believe, giving satisfactory results.

The late Mr. John Price, of Woolwich, patented a heating furnace in 1873, but whether it can be strictly considered a gas-furnace is questionable. It is, however, said to be in successful operation at Woolwich Arsenal.

Mr. W. S. Sutherland, of Birmingham, at the meeting of the Institute in May last, read a paper on his system of gas-heating, which is fully described in the recently issued *Journal* of this Institute,* and to which I need not therefore further refer.

Mr. Jeans, in the course of his important paper, read in 1882, on the "Consumption and Economy of Fuel," referred to the economical results obtained by the "Casson-Bicheroux" puddling and reheating furnaces,† and more recently the President of our Institute, Mr. Samuelson, noted the excellent results obtained in Belgium by the use of this arrangement.‡

I hope that it may be of interest to the Institute to supplement these *data* by giving a brief description of the furnace, as it is applied at several important works in this country.

It is now generally admitted, especially by German and

**Journal*, No. I., 1883, p. 222. †*Ibid.*, No. I., 1882, p. 148. ‡*Ibid.*, No. I., 1883, p. 22.

Belgian ironmasters, that no system of heating yet in practice is so satisfactory in its results as that in which fuel in the gaseous state is employed. Not only is there a saving in the weight of coal consumed and in the price of the fuel used, but this system embodies advantages of still greater importance in an improved quality and yield of iron, steel, or other metal treated. The only question is, Which system of gas-heating is the best and most economical for any given purpose?

As stated at the commencement of this paper, we are indebted to the Messrs. Siemens for a practical gas-furnace giving such satisfactory results as to warrant its adoption wherever sufficient capital is at command. There are, however, many old and respectable firms with much capital tied up in plant, &c. There are also others who have neither the capital nor the inclination to spend *large* sums. It is more especially to such that my system may be of value. Briefly described it is as follows:—

1st. Each furnace has attached to it a separate gas-producer (E), which may be placed at any reasonable distance from the back of the furnace itself. The gas evolved is either exhausted by draught or forced out by blast (F), according to the nature of the coal.

2d. The producer is fed from a large hopper (G), communicating by valves (H) with the ordinary coal-feeders (I), thus dispensing with any hand-shovelling.

3d. The air is heated by passing first into a cast-iron box (J) forming the base of the gas-producer (E), thence into iron or clay pipes (K) built in the producer, and protected by a pigeon-holed fire-brick wall (L), then along the side walls (M) of the gas-flue (N), until it reaches the under side and crown of the fire-bridge (O), where it passes in streams mixing with the gas sufficiently early to produce any degree of heat that may be required.

4th. In Staffordshire and Yorkshire, where this system has been at work for several years, it has been found necessary, owing to the nature of the coal, to apply blast both for gas (F) and air (P).

5th. It will be seen that regenerators are not employed in heating the air, and that the waste gases used for heating these can be utilised for generating steam or other purposes, as in the case of ordinary puddling furnaces fired by coal.

6th. For the same reason existing furnaces need not be inter-

ered with beyond making gas connections; consequently the cost of applying gas to old furnaces becomes a matter of very small outlay.

7th. Each furnace has attached to it two levers communicating with the blast valves, whereby the furnace-man can control to a nicety the quantity of gas or hot air he may require.

8th. Owing to the mechanical feeding arrangements, one stoker is sufficient for three or four mill-heating furnaces.

9th. Except when necessary to obtain a reducing flame, no smoke whatever can be seen from the tops of the chimneys, the dampers of which are never more than about six inches high.

The puddling furnace as constructed on my system differs from the heating furnace:—

1st. In having the producer fixed immediately behind the fire-bridge without any intermediate gas-flue (see Fig. 1).

2d. In the different method of heating the air, *i.e.*, in passing it under the neck and bottom of the furnace (see Fig. 2).

The gas and air are worked under pressure, and the stoking arrangements are similar to those in the heating furnace. Owing to the close proximity of the producers to the furnace the gases are liable to ignite, consequently the saving in fuel is not so great as with the heating furnace arrangement, where the producer is at a greater distance from the furnace; but the furnaces work very economically and well.

At the Round Oak Ironworks all the heating furnaces of the 22-inch, 16-inch, and 12-inch trains are constructed on this system, as well as the ball-furnace and the single and double puddling furnaces of one forge, the largest heating furnace being 13 feet 3 inches by 11 feet by 2 feet 5 inches. The other forge is on the "Casson-Dormoy" principle, but these latter furnaces will be replaced by gas-furnaces as they wear out. I may mention that the only fuel used is slack, as it comes from the pit, if of good quality; if not, the fine dust is removed in revolving screens and consumed under the firing-boilers by means of Henderson's mechanical stokers. The following comparative results of the "Siemens" and "Casson-Bicheroux" furnaces may be of interest, as also the statements of trials, &c.:—

Results Obtained with Gas Puddling and Heating Furnaces.

System.	Where in Use.	How Long in Use.	Puddling or Heating.	Description of Fuel Used (Lumps, Slack, or Screenings).	Fuel Consumed per Ton of Iron Made (at 2240 lbs. per Ton).	Whether Getting up of Steam is Included.	Authority.
Siemens	Castle Iron-works, Wellington, Salop	Twelve years	27 puddling 6 heating furnaces	Shropshire lump coal and slack mixed—about equal to best Staffordshire rough slack	T. C. Q. LBS. 1 19 0 3½	This is the average consumption over the last three years, and includes gas for puddling and heating, and fuel for boilers per ton of finished iron rolled All wire and guide mill iron.	Per pro Nettlefolds Limited, EDWARD STEER, Director.
Casson-Bicheroux	Woodford Ironworks, Soho	From four to five years	8 puddling furnaces, puddling 13 cwt., heats 2 large ball furnaces 7 mill-heating do.	Slack	Puddling about 18c. 2q. 0lbs. Varies with class of iron Varies with class of iron	All these furnaces work to boilers	Morewood & Co., Sept. 5th, 1883.

Extra slack consumed at firing boilers . . 1c. 2q. 0lb.

Results of Experiments made on the 22*d and* 23*d of September* 1880 *at the "Casson-Bicheroux" Patent Gas-Puddling Furnaces, with Iron, Screenings, &c., supplied by Messrs. John Russell & Co.* (*Limited*), *of Walsall, in the presence of their Managers.*

Pig Iron Charged.	Puddled Bars Made.	Loss.	Loss per Ton of Iron Made.	Scrap Bars Made.	Total of Iron Made.	Fettling Used.		Fettling Used per Ton of Iron Made.	Screenings Consumed.	Screenings Consumed per Ton of Iron Made.
T. C. Q. Lbs.	T. C. Q. Lbs.	T. C. Q. Lbs.	T. C. Q. Lbs.	T. C. Q. Lbs.	T. C. Q. Lbs.		T. C. Q. Lbs.	T. C. Q. Lbs.	T. C. Q. Lbs.	T. C. Q. Lbs.
						Pudd. Mine	1 2 2 0	0 2 0 17		
10 16 0 0	10 1 2 16	0 14 1 12	0 1 1 19	0 7 0 6	10 8 2 22	Purple Ore	0 13 0 0	0 1 0 27	7 13 2 0	0 14 2 23
						Bulldog .	0 10 0 0	0 0 3 23		

Results of Experiments made on the 6*th October* 1880 *at the "Casson-Bicheroux" Patent Direct-Acting, Gas-Heating, and Boiler Furnaces, with Fuel supplied by Messrs. John Russell & Co.* (*Limited*), *of Walsall, in the presence of their Managers, in a Two-High-Bar Mill.*

Iron Charged to Furnaces.	Finished Iron Made.		Ends.	Waste in Furnaces.	Percentage of Waste.	Cannock Chase *Slack* Consumed.	*Slack* Consumed per Ton of Iron Made.
T. C. Q. Lbs.		T. C. Q. Lbs.	T. C. Q. Lbs.	T. C. Q. Lbs.		T. C. Q. Lbs.	T. C. Q. Lbs.
	Strip $9\frac{1}{2}$ in. by 10 W.G. .	12 0 2 8					
17 18 1 11	Billets	1 17 3 0	3 0 2 8	0 19 1 23	5·42	4 17 2 0	0 5 3 0

Authority, A. W. HUTTON,

for JOHN RUSSELL & CO., Limited.

NOTE.—Two gas-heating furnaces of Messrs. John Russell & Co.'s Works, built on Mr. Casson's plans, produced 206 tons 15 cwts. of $6\frac{1}{4}$ in. and $6\frac{1}{2}$ in. strips in 10 turns work, and on some of the turns the make reached nearly 24 tons; the average output, however, being about 20 tons per turn, including roll changing, delays, &c. These gas-furnaces are about 10 ft. 0 in. by 7 ft. 6 in., and the time of each heat is about 45 minutes, thus getting out 8 to 9 heats per turn of 12 hours. The saving in the yield and freedom from wasters in these strip-heating furnaces form a very important item in the cost of making gas and steam pipes.

Experiments made at Round Oak Works, 1st August 1879, in One Turn's Work at Two Furnaces in presence of Messrs. N. Hingley & Sons' Managers, to Test Quantity of Slack Consumed per Ton of Iron Rolled and Waste of Iron in Furnaces.

Iron put into Furnaces.	Finished Iron Rails (Rolled).	Ends of Bars.	Waste in Furnaces.	Waste, including Ends of Bars.	Percentage of Waste including Ends of Bars.	Actual Waste.	Percentage of Actual Waste.	Fine Slack Consumed.	Fine Slack Consumed per Ton of Iron Rolled.
T. C. Q. Lbs.	T. C. Q. Lbs.	T. C. Q. Lbs.	T. C. Q. Lbs.	T. C. Q. Lbs.		T. C. Q. Lbs.		T. C. Q. Lbs.	T. C. Q. Lbs.
22 13 1 24	19 4 3 0	2 1 3 7	1 6 3 17	3 8 2 24	15·15	1 6 3 17	5·93	4 12 0 0	0 4 3 3½

Authorities { THOMAS ASHTON, *Mill Manager, Netherton Ironworks.*
WILLIAM YEOMANS, *Forge Manager, Netherton Ironworks.*
N. HINGLEY & SONS, *Netherton Ironworks, Dudley.*

The late Mr. Samuel Davison, of the Horbury Junction Iron-works, Wakefield, wrote as follows:—

"After further trial of your 'Casson-Bicheroux' gas generators, I have very great pleasure in bearing testimony to their great efficiency and economy in working. This is most particularly the case with our re-heating furnaces, as the following figures will show, viz.:

Ball Furnace Account.

	Coal used.				Iron produced.			
	T.	C.	Q.	Lbs.	T.	C.	Q.	Lbs.
Week ending September 16 . .	22	3	0	0	72	8	0	14
,, ,, September 23 . .	20	19	0	0	75	18	2	24
,, ,, September 30 . .	21	19	0	0	76	7	0	8
,, ,, October 3 . . .	22	18	0	0	75	1	0	0

Giving an average (87 tons 19 cwt.—299 tons 14 cwt. 3 qrs. 18 lbs.) = 5 cwt. 3 qrs. 13½ lbs. per ton of coal on iron produced. And when I explain that under the old system we regularly used about 9 cwts. of coal at 7s., against 5 cwt. 3 qrs. 13½ lbs. at 5s. 9d. now, you will see how great the saving is. Our yield of iron is better, quality more uniform, and repairs much less."

At the Round Oak Works horizontal boilers are fixed over the furnaces, heated by the escaping gases. Annexed are the results obtained by Mr. Edward Woods, C.E., of Westminster, and Mr. Rupert T. Smith, C.E., of Birmingham, from one of these boilers, as compared with two other hand and mechanical firing boilers:—

Comparative Trial of Boilers, Hand-Fed, Mechanically-Stoked, and Heated with Waste Gas, from Casson-Bicheroux Mill Furnace at Round Oak Works, 8th October 1880.

Boiler.	Fuel.	Heating Surface in square feet.	Grate Surface in square feet.	No. of lbs. of Water evaporated by 1 lb. of Fuel, calculated from 212° Fahrenheit.	No. of lbs. of Water evaporated per square foot of Fire Grate per hour, calculated from 212° Fahrenheit.	Coal burnt in lbs. per hour.	Clinker.	Ash.	Total.	Smoke.	No. of lbs. of Water evaporated per hour.	No. of lbs. of Fuel burnt per square foot of Fire Grate per hour.	Deposit of Soot in lbs.	Clinkers reburnt in lbs.	Temperature in Flue in degrees Fahrenheit.	Draught in Flue in inches.	Remarks.
Hand fed . .	Rough slack	246	45	4·89	120	1107	4·5	5·8	10·3	Moderate	5,413	24·6	...	None	1,575	$1\frac{7}{16}$	Draught too great.
Mechanically stoked . .	Fine slack siftings	246	14·25	7·04	381	771	4·9	2·8	7·7	No smoke	5,428	54·1	...	None	1,075	$1\frac{1}{8}$	Draught too great.
Waste gas from mill furnace	Kibbles	302	...	6·58	...	388	...	...	...	No smoke	2,554	...	...	...	...	...	...

Hand-fired boiler, rough slack, at 4s. per ton, and taking the power at 30 H. P. = ·791 of a penny per H. P. per hour.

Mechanically-fired boiler, siftings, at 2s. per ton, and taking the power at 30 H. P. = ·275 of a penny per H. P. per hour.

Gas-fired boiler from waste gas after heating iron in mill furnaces, kibbles, at 4s. per ton, and taking the power at 20 H. P. = ·416 of a penny per H. P. per hour.

Subsequent experiments resulted in like proportions of coal used and water evaporated.

The cost of erecting gas-furnaces on my system is approximately as follows :—

For a large heating furnace, capable of heating 10 tons per turn . .	£250
For two furnaces, with producers, together	425
For a double-puddling furnace, capable of puddling 3 tons 10 cwts. per turn, or 7 tons night and day, *i.e.*, a furnace equal to three ordinary furnaces	150
This does not include a puddling machine.	
For a single puddling furnace, worked by hand	90
Or an old one converted	40

As compared with the above costs, Mr. George Allan of the New British Iron Company's works, near Birmingham, writes as follows :—

"Replying to your inquiry as to our gas furnace and producers, I think you may take the respective costs as follows, viz. :—

One Siemens pile-heating furnace for 16-inch merchant mill, including the necessary excavation, clearing of ground, &c.	£495
One Wilson gas-producer for working the above, including all royalty charges, clearing and excavating the ground, &c.	185
Culvert for conveying gas from producers to furnace, including excavation, materials, and labour	69

"The furnace is of such a size that we can heat 8 to 9 tons of piles per turn. It is of the usual 'Siemens' type, and there is practically no waste heat delivered into the chimney. We incurred no cost for a chimney, as we simply connected it to the old stack, which served the air-furnace it substituted. I find it a very decided advantage to have a separate chimney to each furnace, as the working condition of the furnace can by this means be better watched and controlled. We put down two Wilson producers to our first furnaces, but as only one is really required per furnace, I have given the cost of one. The gas-flue is available—with a very slight extension—for other three furnaces. The cost of this item given above should therefore be reduced.

"In addition to the above costs, other £30 per producer should be allowed for platforms, &c. &c., which brings the outlay for a furnace of the size I have indicated up to say £779. We have now had our first furnace and producers at work some six months, and I do not know that I could suggest any modification which would materially reduce the cost."

With regard to the history of gas-puddling in this country,

and the reasons why it has been as yet applied in comparatively few instances, Messrs. Morewood & Co., of Birmingham, have favoured me with the following letter:—"You ask us what has impeded the introduction of these furnaces? We are afraid that we cannot enlighten you very much on this point, and the only conclusion that we can come to is, that the ironmasters of this district are adverse to trying anything new." Mr. John Williams, manager of Nettlefolds, Wellington, Salop, writes:—"The reasons why gas furnaces have not been generally used for puddling may be condensed into one word—'prejudice,' as the saving of coal and pig iron is an undeniable fact, even here, where we have to raise steam separately, and it would be much more so where steam enough was raised by half a forge worked by any other process to supply the second half with gas."

The late Sir William Siemens wrote:—"In reply to your inquiry, the application of regenerative gas-heating furnaces made in this country and abroad are too numerous for me to specify. The advantages of the regenerative gas furnaces, as compared with solid-fuel furnaces working under the same conditions, are a saving of about one-half the consumption of fuel, and a saving of about one-half the waste of iron. Besides these, they offer the further important advantage of cleanliness and of better work, owing to the absence of ashes, and of cold draughts in the heating chamber. With regard to puddling, the regenerative gas furnaces have been extensively applied at the works of Nettlefold and Co., at Wellington, of Clay, Inman, & Co., Birkenhead, and of Lee & Bolton at Stourbridge, where they have given much satisfaction; but I have been so much engaged with the production of steel on the open hearth that I have not pressed the application. A drawback to the adoption of the regenerative gas furnaces for puddling, and to their use in substitution for the ordinary reheating furnaces, has up till now been their first cost; but recently I have brought out a new form of regenerative gas furnace which removes this objection; it is already extensively adopted for heating retorts in the furnaces at gasworks, and will be gradually introduced for other applications."

I believe that other reasons may be added, such as a fear of the outlay involved, and a doubt on the part of managers as to their capability to control the altered system of working—a

fear which, in my opinion, they need not entertain, as any intelligent and practical man acquainted with ordinary firing-furnaces could easily deal with my gas system. Again, the coal in some of the more important iron and steel making districts is of too bituminous a nature to be successfully applied in gas-producers of the present type; but whilst this applies in a greater or less degree to the Middlesbrough district, it has no application to Staffordshire, Shropshire, Yorkshire, Derbyshire, or Scotland.

It is the opinion of those who have had my gas system in operation for some time, based on the tests they have made, that the heat obtained is sufficient for the manufacture of steel on the "open-hearth" system; but this is a question which can only be proved by actual experiments with a steel furnace. In any case, I trust that I have clearly shown that a thoroughly reliable and economical gas-heating furnace is being gradually introduced to the iron and steel industries at a moderate outlay, without the necessity of the costly and troublesome "regenerator," whilst enabling the waste gases to be utilised for raising steam or other purposes.

ON THE MOST RECENT RESULTS OBTAINED IN THE APPLICATION AND UTILISATION OF GASEOUS FUEL.

By Mr. W. S. SUTHERLAND, Birmingham.

What is known as producer gas is very much akin to the gas evolved from blast furnaces in which raw coal is the fuel used; and the methods adopted in the one case to recover the tar and ammonia, and leave a clean pure gas for after combustion, are applicable to the other. It is probably known to most members of the Institute that Messrs. William Baird & Co., of Gartsherrie Ironworks, have for several years devoted a certain amount of attention to the recovery of bye-products from their blast-furnace gases; and to show what is practicable in this matter, I am authorised to state the following facts, which have been supplied to me by Mr. M'Cosh, one of the partners of that firm.

At Gartsherrie, and at their Eglinton Ironworks in Ayrshire, Messrs. William Baird & Co. have now erected and at work plant for the recovery of the tar and ammonia from the gases of sixteen of their blast furnaces, consuming about 1000 tons of coal daily. At the present time this plant is only working up to two-thirds of its power, owing to a want of exhausting power and a break-down of one of the exhausters. They manufacture the ammonia into sulphate, and they distil the tar into oils and pitch. The gases at their different works contain ammonia equal to from 20 lbs. to 30 lbs. of sulphate, and 200 lbs. to 225 lbs. of tar per ton of coal consumed—the yields varying with the qualities of the coals, and also with the working of the furnaces. The ammonia and tar are very perfectly taken from the gas, but hitherto various sources of loss have crept in, and the actual yield attained varies from 18 lbs. to 25 lbs. of sulphate of ammonia and 180 lbs. to 200 lbs. of tar per ton of coal consumed. The gas, after being treated, is perfectly clean, as well as free from moisture; and as it deposits practically no dust, it is found to be better adapted than before for all purposes of the works—for raising steam, heating the furnace blast, distilling the tar, &c.

This plant has now been at work for about six months, and part of it, equal to two furnaces, for eighteen months, and Messrs. Wm. Baird & Co. are going on extending their Gartsherrie plant so as to embrace the whole of their blast furnaces there.

The diagram exhibited (Plate III.) gives an outline of the plant for dealing with the gas. I may add that it has been erected under patents granted to Mr. Alexander and Mr. M'Cosh, both of whom are partners in the firm of William Baird & Co., and with whom I am pleased to be associated in this work of purifying blast-furnace and producer gases and obtaining bye-products therefrom.

The production of generator gas is, without doubt, the simplest process, in principle, in the whole range of the gas manufacture, and yet, at the same time, it is a very complex process, the variable results attending which are not yet thoroughly understood, although so many thousand tons of coal are yearly employed in its practical working. It is true that a very fair average quality of gas can be obtained from the useful primitive structures which have proved such good every-day working tools. But their great inventor, whose loss we must all so much regret, did not himself consider them perfect, though they perfectly fulfilled his object—the production of a cheap gas to be used in conjunction with regenerators. Those who have practical experience in working producers, of whatever type they may be, will recognise how important a point it is to be able to break up easily the mass of fuel contained in them, to keep them open and of the right degree of porosity, and yet to avoid their breaking through into large holes. They will say, too, how much the attainment of such results adds to the labour cost, while they are essential to the uniform and successful production of good gas.

It is entirely by careful attention to this point that the fire is prevented from becoming dead, with a mass of solid uncoked fuel above bearing directly upon it, instead of passing gradually from a full, white heat to a glowing red coke, and then partially coked coal, with the raw coal drying on the top, which is about the ideal of good working; or, if the fire be not dead, it is allowed to blaze away through some chimney-hole formed in the fuel above, with the heat all concentrated in the one spot, and a furnace temperature of sometimes 1800° to 2000° Fahr., or even more, in the top of the producer over the coal, and the consequent inevitable

loss of heat, and passage of bad gas, loaded with sulphurous acid, into the furnace. Now, regenerators have such a marvellously steadying action that this sort of thing may go on to a considerable extent, alternating with the production of good gas, without, in many applications, interfering with any other result than the economy of fuel; and in blast furnaces, which are gas-producers of a very highly efficient type indeed, this compensating action is obtained by the enormous depth of fuel, which practically gives the combining surface absolutely required, even though there be large holes in the fuel, and allows, in addition, plenty of time to coke the coal and prepare the fuel, although at the expense of enormous driving power. This driving power is allowed for and submitted to in blast furnaces, where good iron is the chief thing to be made, and not gas or gas products; but in gas-producers, I fear, a driving pressure of some 4 or 5 pounds per square inch would be out of all question.

Now, since the main object of a gas-producer is to expose a sufficient surface of incandescent fuel to the current of air passing through it, and thus to convert the whole of the oxygen in that air into carbonic oxide before passing up through the upper layers of fuel, it follows that all producers should be so arranged that if the fuel be sodden down in a lump or broken through into holes, the parts that are out of order can be instantly attacked and restored to their normal condition. When coal is put into a retort, gas of a certain quality can infallibly be produced from that coal, if only the fire can be kept up under the retort. I submit that the same thing ought to obtain in the making of generator gas, and that if this be not so—if the conditions necessary to produce the highest possibly quality of gas be a matter of chance and uncertainty, and not attainable at a moment's notice—the system is so far a failure.

Now, the measure of the quality of producer gas is the amounts of carbonic acid and pure oxygen present in the gas, and the temperature at which the gas escapes from the producer, and as well of the quantities and qualities of the tar and ammoniacal products. In general, the quantity of CO_2 will vary from 4 per cent. to 7 or even 9 per cent. in some producers, whilst the temperature of the escaping gases varies from 1200° F. to 2000° F., and the tar, owing to the coal not having been thoroughly coked

before the formation of CO_2 has ceased, will be found to be charred and of little value, while the ammonia will be partly destroyed, and any that remains will be found to be in the form of fixed salts or sulphites. A result of the experience I have had in this matter is the conviction that the common plan of working producers by hand labour is a totally inefficient one, which leaves the quality of the gas produced a matter of chance, dependent upon whether the teazer can discover the sore place in the producer, and that is often attained only after severe and exhausting labour. To obviate this difficulty, I have pointed out, in a previous paper, that "mechanical stirring should be resorted to," and the plan which I have adopted for that purpose I now beg to describe.

The producers, Plates III., IV., and V., are of cylindrical form. A vertical revolving spindle passes through the centre, carrying on the end a stirrer to plough up the fuel. This is made preferably diamond-pointed, to enter and loosen the fuel, and carries two arms, like propeller blades, which screw their way into the fuel, and at the same time loosen it and break it up effectually. The top of the spindle is cut into a screw, which moves through the nut in the girder overhead. The spindle is worked up and down by the gearing shown on the diagram (Plate VI.), and is controlled by the right and left hand clutch gear shown; while the whole is driven by a small engine. As only one producer needs stirring up at a time, very little power is required to do the work; and as the labour on the top of the producer is thus limited to putting in the coal, and working the clutch levers (if, as is generally the case, the coal be brought up in suitable trucks), it will be found that the economy realised will be considerable. I have found that, with high speed, in gas-producers about 4 feet in diameter, up to 5 cwt. per hour of coal can be worked through, and that if the stirring be properly done no carbonic acid may appear in the gas, whilst 2 or 3 per cent. of it, and no free oxygen, should be looked for at the most.

But I do not believe, after allowing for the CO_2 present in the coal, that it is possible to attain such results always by hand labour, and whilst I estimate that by the use of mechanical stirring the labour on the whole producer can be brought down to somewhere about 4d. to 6d. per ton, a very great saving can certainly be effected by improving the quality of the gas produced. I am also

quite sure that in order to get tar and ammonia of good quality good stirring and low heats on the top of the fuel are absolutely necessary. At present there is not much to add to the description which I gave in my last paper of our apparatus for getting those products from producer gases. In order to obtain good gas and bye-products, the gas must be well cooled. If the gas be not cooled down, the quantity of water which it will suck up from the washing apparatus is so great as to destroy the value of the gas for heating purposes, whilst the ammonia is carried bodily away, even if it be in the form of fixed salts or sulphates, and the lighter and more volatile constituents of the tar are carried forward and burnt. At present, the maximum quantity of ammonia sulphate obtained per ton of coal is about 20 lbs., but I am well aware that more may be got by sacrificing the gas, because it appears that if steam comes in contact with hot fuel in such a way that carbonic acid is produced instead of carbonic oxide, the nitrogen in the fuel is eliminated in the form of ammonia, and at first glance, since each atom of CO formed in this way into CO_2 liberates its equivalent of hydrogen, there would appear to be no loss of heat, but the carbonic acid formed is equivalent to so much additional nitrogen; it is, in short, a dead weight fastened on, and every one who has to use gas knows how desirable it is to get the very best quality attainable. The quantity of tar got varies with the nature of the coal, perhaps more so than that of the ammonia, but about twelve gallons appears to be about the normal quantity.

It must not be forgotten, however, that the depth of the fuel has an important bearing upon this production, as shown by the figures I have already given. There is another advantage in good stirring which is of no small moment, and that is, that the gas leaves the producer so much cooler, which represents great economy of fuel, much less cooling surface in the condensers, and less water for finishing the condensation. There are several other vital points to be attended to in getting the triple products—generator-gas, tar, and ammonia; but we are now finding that this gas, of high quality, can be got with certainty along with up to 20 lb. of sulphate of ammonia per ton of coal, and from 10 to 20 gallons of good tar. The labour upon the producers and plant can be reduced to about from 4d. to 6d.

per ton of coal passed through, and thus a net saving of about 2s. 6d. to 4s. per ton of coal may be effected.

Now I have no doubt I shall be asked, What about the quality of the tar produced? Well, we do not profess to make tar of the same quality as the gasworks tar. The aromatic series is not formed at the present time, but it is a fact that the whole of the enormous quantity of tar above referred to is being put into the market, and that it is all disposed of, although for what purposes I am not prepared to say. It is also true that benzol and the aromatic series are in part being prepared from this class of tar in considerable quantities, and if any doubts occur to your minds as to the uses to which these tars are to be applied, let me remind you that the matter is only in its infancy, and that new uses are being constantly found for these products, while it is a fact that in Scotch oilworks, if the value of the residual tar produced goes down to four times the value of the fuel used to heat the retorts, it is found advantageous to use it as fuel under the retort instead of the coal generally employed. Reasoning from this fact, it would appear that the time is not far distant when tar or tar and paraffin oil will be the fuel used on steamships, whereby only about one-half the present space, or even less, will be taken from cargo room. There will also obviously be an enormous saving in the labour of stoking, and an absence of smoke.

In conclusion, I would wish to point out what a fallacy it is to suppose that the condenser forms the bulk of the cost of the plant; on the contrary, I can show, on any estimate, that it is not more than from 25 to 30 per cent. of the cost; and I can show, too, that the extra tar and ammonia produced is sufficient not merely to pay for this, when taken in conjunction with the necessity of drying the gas to get good heating power out of it, but to pay as well for the whole of the plant put down. I should wish you, moreover, to recollect that in blast-furnace practice, as well as in gas-producers, the use of the gases for heating stoves and boilers, and for evaporating, is of far too great importance to be neglected. So far from the elimination of the tar and the cooling of the gases interfering with their heating power, it is found at Gartsherrie that in this way a less amount of gas is used even than before.

DISCUSSION.

Mr. HEAD (manager for the representatives of the late Sir William Siemens) said he was very well pleased to respond to the invitation of the President to take part in the discussion on the two papers which had just been read. He thought that had Sir William Siemens been spared to them, he would have been interested in those papers, because, although they did not follow out his ideas thoroughly, they did adopt some of the views which he had advanced upon combustion. There were two papers before them, one of which had reference to gas furnaces, and the other dealt with the production of gas. With regard to the latter, the feature which had been most prominently brought before them was the recovery of tar and ammonia from producer or blast-furnace gases. Upon that subject Sir William Siemens and he had had several discussions; Sir William Siemens took the view that tar and ammonia formed part of the volatile constituents of coal, the other gases made from the destructive decomposition of coal being only a combination of air and steam with carbon. A few weeks ago, however, Mr. Foster read a paper before the Institution of Civil Engineers, in which it was shown by chemical analysis that some nitrogen was resident in coke, and it was suggested that, under certain conditions, it would be possible to evolve that nitrogen in the form of ammonia. He believed that this had only been done experimentally so far, but if that scientific deduction could be realised in practice, the ideas he was about to express would have to be modified to some extent. Sir William Siemens considered that if the recovery of tar and ammonia from coal gases to be used for furnaces was to be effected, the best way to do this would be to distil the coal in retorts, in the same way that it is done at gasworks, and to convert the hot coke, as it leaves the retorts, by means of gas-producers, thus making two separate operations of the decomposition of coal. By adopting that course, only about 10,000 cubic feet of gas per ton of coal would have to be treated for the recovery of tar and ammonia, whereas the same weight of coal would yield from 160,000 to 180,000 cubic feet of gas if entirely converted in the producers, and the gas from the coke could be enriched by

the addition of those hydro-carbon gases obtained from the retorts which were not required for other purposes. Dealing with 10,000 cubic feet of gas instead of from 160,000 to 180,000 cubic feet, of course meant a considerable saving in plant, as the enormous condensers, exhausters, &c. that would be required for treating the larger quantity were somewhat frightening in their aspect. The only point which seemed to him to have any bearing on Sir William Siemens' suggestion was, as before said, whether the nitrogen which Mr. Foster had found to be associated with coke could be abstracted by means of steam, and thereby a certain amount of ammonia obtained, and whether that amount of ammonia would be worth the trouble involved in extracting it. He did not find from the paper of Mr. Sutherland that the amount of ammonia from the blast-furnace gases was any greater per ton of coal than that obtained in gasworks. He was not thoroughly acquainted with what was done at gasworks, but the amount did not strike him as being very much greater, while the amount of tar must, of course, be the same, for there could be no difference in that respect, whether the conversion was effected in retorts or in gas-producers.

With regard to Mr. Smith-Casson's furnace, that gentleman justly pointed out that it was not a regenerative gas furnace. It was simply a gas furnace, and as such it might perhaps offer the advantage of a little better combustion than was obtained in the ordinary furnace, involving absence of smoke coupled with purity of flame, but otherwise it could not be of any advantage. The air was heated by taking away heat from the gas; and by equalising the temperature between the two currents no doubt better combustion would be obtained in the furnace, because if hot gas and cold air be introduced into the furnace, they would not burn properly together. Thus, by robbing the gas to pay the air they no doubt got better combustion, but that did not, to his mind, imply economy in fuel; there would be more economy in fuel in the form of furnace in which the inflowing air was heated by being passed under the bottom of the furnace, but that would not be great. In the paper presented to the Institute he noticed that nothing was said about the amount of steam used in the gas-producer. He had had some experience with producers supplied with steam, and if they were worked at a very small pressure it

was advantageous, under certain conditions, but if a high pressure be used, there would be a positive disadvantage in using steam. The producer, illustrated by the author, was similar in form to that which the late Sir William Siemens adopted so far back as 1864 or 1865, and it would be found in Dr. Percy's book on "Fuel," published in 1875, exactly as it was depicted on the diagram, or substantially so. But what Sir William Siemens had last done was to use hot air in the gas-producer, and to introduce it with a little steam into the midst of the fuel in order to attain decomposition at a very intense heat. He made some experiments in reference to the production of gas under those conditions, and found a great advantage in it; for the amount of carbonic acid was notably reduced from what it was in gas made in ordinary producers, which, as stated in the paper, contained between 4 per cent. and 7 per cent., the lower figure representing a very fair result indeed, according to his experience. The experiments referred to he had made in October last, and the results obtained formed the subject of the last report which he had addressed to Sir William Siemens. The producer used was a circular one, with an open ashpit of Sir William Siemens' latest design, and it contained about 4 tons of coals, and he had had it under his supervision for some hours previous to taking a sample of gas for analysis, which was found to contain only 2 per cent. of carbonic acid and ·2 per cent. of free oxygen. He regretted to say, however, that an accident in his water supply prevented him from completing this analysis; but he took another sample of gas made in this apparatus by the men, and he found that in ordinary practice they were working with about 3 per cent. of carbonic acid and ·8 per cent. of free oxygen, the gas made containing from 26 to 27 per cent. of carbonic oxide, with a large proportion of hydrogen and hydrocarbons, or altogether about 48 per cent. of combustible elements. This forms a very good gas—in fact, it was 40 per cent. richer in combustible elements than gas made from the same coal in an ordinary gas-producer, as shown by analyses which he had made. With such a rich gas, Sir William Siemens wanted to bring in a furnace which should have simply a regenerator for air, and he had devised a simple and efficient form of regenerator for that purpose. It had been applied largely at gasworks with beneficial results, furnaces for two thousand retorts having already been

built in this country; but he had not yet succeeded in this country in getting the furnace applied to heating and to puddling, although he hoped that would soon be done, for such an application would be attended with a considerable saving in construction as compared with the form of regenerative gas furnace with four regenerators and reversals. A furnace of that form had just been set to work in Spain, and was used for welding iron; but he had not, up to that time, received any particulars as to the consumption of fuel or the work done.

Mr. Kitson said there was one point which occurred to him with reference to the return as to the puddling done by Messrs. Morewood & Co. Eighteen and a half hundredweights of coal was given as the amount of coal consumed per ton of puddled iron produced. It occurred to him to ask how far the economy had been effected by the use of the double puddling furnace rather than by the method of firing adopted? In double puddling furnaces fired by the ordinary method, a consumption of from 15 cwts. to 16 cwts. of coal per ton of iron was commonly required, so that, except as regarded the quality of the coal used, he failed to see any very great economy, judging by the return of Messrs. Morewood & Co. It also occurred to him to ask Mr. Smith-Casson whether they were able to obtain, at certain stages of the puddling process, that pressure of flame and that excessive heat which were required when the puddler had to clear his iron. From reports, and from the result of his own practical examination of these furnaces, he had learned that for high qualities of iron, where it was very necessary that the iron should be particularly well cleared, they failed to obtain the high temperature that was required at that period of the process. It might give an excellent constant flame, and yet not be under that control which was required in puddling special qualities of iron.

Mr. James Riley desired to say a word or two with regard to Mr. Sutherland's paper. One would suppose that those who were largely interested in the use of producer gas must be very much behind the times, or not paying that attention to those matters which it was desirable should be done. He had, however, had several conversations from time to time with Mr. Sutherland on

that point, and he had been posting himself as well as possible, and keeping abreast of the progress made in that direction. But to tell the truth, he felt himself in the position of not daring to make a step at that moment. Mr. Sutherland had always pointed out to him the great saving that could be made by utilising the bye-products. In fact, at one time he almost came to believe that instead of its being the case that the tar and ammonia were to be the bye-products of their system, the making of steel was to be the bye-product. But the more he looked at it, and the more experiments he had made with regard to that point, the farther away had the realisation of those economies appeared. In the first place, from a common producer—and this was the essential point—they could obtain no more than from 4 lbs. to 11 lbs. of sulphate of ammonia. It was a very doubtful quantity, and the point they should all give their attention to, more than the scrubbing or anything else, was the best form of producer. That problem he put before Mr. Sutherland some four or five months ago, and that gentleman left him with the assurance that that point would be attended to in two or three days or weeks, he did not know which. He now saw Mr. Sutherland that day for the first time since then, and he guessed that the problem was still rather difficult for him to solve. There were several forms of producer, and the difficulty was to arrive at a decision as to which was the best one. He was wavering between the two plans of either distilling the coal in the retort, as had just been described by Mr. Head, or using a blast-furnace producer. Which of the two would be the ultimate outcome of his inquiries, or whether it would be some other, he did not know. It was, indeed, an extremely important point, and he looked upon that gigantic scrubber and condenser, and all the arrangements required for dealing with the blast-furnace producer with some amount of terror; whereas dealing with a small quantity by the process Mr. Head had described, and which was working admirably in the gasworks in Glasgow, was not so formidable a matter.

After some remarks from Mr. T. R. Crampton,

The President said that, before calling upon Mr. Smith-Casso[illegible] and Mr. Sutherland to reply, it might be useful that he shoul[illegible]

read a letter which he had received from Mr. Andrew Carnegie, of Pittsburg, in order to show what was being done with gaseous fuel in America. He said: "I wish you would come and see my works running by natural gas, led in pipes nine miles, and to our works in the city, nineteen miles; not a pound of coal is used either for puddling or heating, or under the boilers. The same in the steel rail-works; a small jet led under the boilers at the blast-furnaces ignites the gas, and we do not use one pound of coal in these works now. Is not this the rich land—rivers of oil and lakes of gas?" They had to compete with that country in which oil flowed in rivers and gas was evolved in lakes, and therefore it certainly was of importance that they should endeavour to economise fuel so far as that was possible. It had been prophesied for a long time that no more wrought iron was to be made in England, and that puddling was to come to an end. But the returns of the British Iron Trade Association showed that within the last year 2,700,000 tons of puddled bars were produced in this country. And there was reason to believe that the quantity of puddled iron produced in the world was still considerably over 8,000,000 tons per annum. Therefore if they could realise any economy in puddling and heating iron by gas, it certainly was an important matter to look to.

That the Bicheroux furnace was a practical furnace he thought they might take to be the fact. So far back as 1877, a paper was read on the use of that furnace at the Ougrée works, in Belgium. He found from a letter received from M. Trasenster, who was the engineer of those works, that those furnaces were at work there to the present day. By those furnaces, 20,000 tons of iron were produced annually, and the results obtained fully confirmed their advantages. In fact, they were rather better even than the results which had been stated by Mr. Smith-Casson. The average consumption of coal per ton of iron puddled was 11 cwt., and the waste was considerably less than in the ordinary puddling furnace. Instead of being from 13 to 15 per cent., the waste was only from 9 to 10 per cent. The cost of the system was said not to exceed £80 per furnace. For heating furnaces the economy was stated upon the actual working to be equally great, so that that was certainly a matter which the proprietors of forges in this country would do well to bear in mind, and to

give more attention to than appeared to have been the case hitherto. He would now conclude by calling upon the meeting to give a hearty vote of thanks to the authors of the two papers—Mr. Smith-Casson and Mr. Sutherland.

A vote of thanks was passed accordingly.

Mr. Smith-Casson said that the representative of Messrs. Siemens had thought proper to make some remarks condemnatory of the system that he advocated. In the first place, Mr. Head had drawn attention to the fact that Mr. Smith-Casson obtained the heat for the air by robbing the gas. He should like to ask Mr. Head what was done in the Siemens furnace? He understood that the temperature of the gases was first of all reduced before they were drawn to the furnace; so that really he simply used what they wasted to raise the heat of the air necessary to produce combustion, and got his air at almost the same temperature as the gas. With regard to the steam that was necessary to obtain the blast, he found that an inch and a half steam-pipe, working with about 40 lbs. pressure, would give sufficient steam to raise blast for two heating furnaces, capable of turning out 20 tons of iron per turn, so that the steam necessary to obtain the blast was not a very great consideration, especially as the waste gases from the furnaces were utilised for raising steam, giving besides almost sufficient steam to drive the mill engine, so that there was nothing lost in that respect. Mr. Kitson had drawn attention to the fact that Messrs. Morewood & Co.'s furnaces were double puddling furnaces. That was so. Mr. Kitson also stated that at some double furnaces 15 cwt. of coal was considered to be a pretty fair average. Mr. Smith-Casson believed that was the case in the North of England; but they must bear in mind that the north-country coal was a far more economical coal than the South Staffordshire coal. They would find that whereas in South Staffordshire an ordinary puddling furnace took about 30 cwt. of coal per ton of puddled iron, in the North they could puddle with about 25 or 26 cwt. That was comparing the large coal of South Staffordshire with the lumps of the North. But, then,

Messrs. Morewood stated that they burned not coal, but slack. Now slack contained a larger proportion of ash than lumps, and an allowance should therefore be made for its use instead of lumps, so that by Messrs. Morewood's statement there was a considerable economy even in point of consumption of fuel, to say nothing as to the difference between the price of slack and that of lumps. But he would also observe that on page 6 of his paper he did not claim any very great economy as regarded the puddling furnace, for the simple reason that, the furnace being so near to the producer, the gases were ignited, and so there was not the same saving; but the great advantage, in his opinion, lay with the heating furnace. He felt satisfied that they could do as had been stated; they could heat a ton of iron with about 5 cwt. of screened slack, and raise the steam besides; and he did not think there was a gas furnace, not even those on Siemens' system, which could show better results. Not only was there a saving in fuel, but it was also to be noticed that the altering of furnaces to this system involved very little outlay, whilst the cost of altering furnaces to the Siemens system meant the taking up of old plant and rebuilding.

Mr. Sutherland wished to say, in answer to Mr. Head's remarks, that he had had the pleasure of being introduced to Sir C. W. Siemens before his death, and he told him that his system of extracting tar and ammonia was a good one, and one that could be carried out very well. Sir William also told him that he was very glad he had taken it up. It was true that they did not get much ammonia from the coke; but he considered they were doing very well if they got practically the same results as were obtained in gasworks, as far as the ammonia was concerned, and very well indeed if they got the same quantity of tar. In fact they got more tar on account of the stuff being distilled at a lower temperature; but the tar was not quite of such good quality, because, to get the highest quality of tar, they must have a higher temperature than could be obtained by that furnace. Again, in those producers they were working at a high pressure; the producers were working at a velocity which was sufficient to burn about 5 cwt. an hour, a speed which he supposed that no producer double the size had attained up to the present time.

The stirring was found to be an excellent thing. It was not the result of theory, but of tentative experiment; and when he said that the thing was necessary, he was speaking from experience. With regard to what Mr. Riley had said, he could only reply that inventors were never satisfied. They were always trying to improve. The system had been working satisfactorily now for some three years. In the very first plant they got certain results which they kept improving upon, and he would be happy to show Mr. Riley at any time, if he would give him the opportunity, a plant by means of which results had been obtained fully equal to those obtained from gasworks plant. He could show him plant working without regenerators very nearly up to the welding point of iron. At any rate, it was at such a heat that the furnace, the other day, was on the point of melting. Then as to the cost of the plant, his plant, looking to the speed at which they could work the producers, would be found to be much cheaper than gasworks plant, and when they looked at it from the point of labour-saving, they would find it was very much cheaper. The handling of the coal, the time it took to do it, and the bulk of the plant required to work a certain quantity of coal in the gasworks plant, would be altogether out of comparison with the quantity that could be dealt with in those little producers. If they took the size of the producers and the size of the cooling plant into consideration—and that was the only fair way to do it—they would find that the cost per ton of this process was far below that of any gasworks in the kingdom. No plant in the world at all approached theirs in economy. With those producers they could deal with the coal, and could have the temperature on the top sufficiently low to get those products, and that was the main thing. The amount of coal now being dealt with by such means amounted to something over 1000 tons of coal per day, and the quantity of ammonia being put into the market was about 3000 tons a year. The quantity of tar being put into the market was somewhere about 20,000 gallons. The thing was still in its infancy, but it was growing. The other day he was in certain works where they burnt somewhere about 2500 tons of coal during the week, and there the idea was to make the gas somewhere about half a mile away from the works, for reasons of cleanliness, and to take the whole of the gas required

in mains up to the works, in the same way that gasworks would do, thus doing away with all smoke and dirt, and all nuisance in the works, which were left absolutely clean. That was what their process was practically doing. The licenses now granted represented over 1,000,000 tons of coal per year, and the thing was being gradually extended. No doubt in time, in places such as Widnes, where some 40,000 tons of coal per week were now being consumed, causing it to be known as the black spot on the Mersey, there would be no smoke whatever. Indeed, instead of continuing to have smoke, they would be able to make what was now smoke into money.

The meeting was here adjourned until the following day

THURSDAY, MAY 1st.

The meetings of the Institute were resumed this morning—B. Samuelson, Esq., M.P., F.R.S. (President), again occupying the chair.

The following paper was read :—

IRON AND STEEL PERMANENT WAY.

By Mr. WALTER R. BROWNE, M. Inst. C.E.

The use of Iron and Steel for the making of railway sleepers was treated before this Institute in a very able paper by Herr Gruttefien, read at the Düsseldorf meeting in 1880. Since that date it has been considered in this room before the Institution of Civil Engineers, in a paper read by Mr. Charles Wood, and printed in the "Proceedings" (vol. lxvii. p. 1). The question was again alluded to in a paper on "Iron and Steel Permanent Way," read by Mr. R. Price Williams, and printed in the "Journal of the Institute" (1881, page 108), where attention was drawn to the steel sleepers laid down by Mr. Webb near Crewe. In these papers, and in the discussions which followed, there will be found a very large amount of information, both historical and practical, bearing on the subject; but so far as the writer is aware, the result has not been to advance in any appreciable degree the substitution of metal for wood as the material of sleepers on English railways. Believing fully that this substitution is only a question of time, and having taken for some years a very keen interest in the problem, the writer is anxious to bring its present position once more before the iron and steel makers of England—the body most vitally interested in the solution of the problem.

Every engineer who is conversant with the technical literature of Germany must be aware that the superiority of metal over timber sleepers, and their eventual substitution for them, is there no longer a matter of doubt. The fact is practically admitted on all hands; the miles of line laid with metal are counted by thousands, and the weight of iron and steel employed by hundreds of thousands, if not millions of tons. The points which do remain in doubt, and on which controversy still rages, concern merely the precise form which the permanent way of the future is to take—whether the metal is to be iron or steel, whether the sleepers are to run lengthwise or crosswise, and what is the particular mode

of fastening to be adopted for uniting them with the flat-footed rail which is the general type on the Continent.

With these questions the writer will not here concern himself. His object is to discuss solely the introduction of iron or steel sleepers in England. Now, to any one acquainted with English railway engineers, it will be tolerably clear that no system is likely to meet with any favour unless the new sleeper is able at once, and without inconvenience, to replace the old one. With one marked exception, the main lines in England may now be said to be laid with double-headed rails in cast iron chairs resting upon a transverse sleeper; and if an iron sleeper is to be speedily adopted, it must be one which can go at once into the place from which an old wooden sleeper has been withdrawn, utilising the same rails, and, if possible, the same chairs as before. This being so, the whole subject of longitudinal sleepers (which have met with much favour in Germany) may here be left out of discussion. In the single exception alluded to above, namely, that of the Great Western Railway, such sleepers should indeed be of special utility in replacing the very expensive oak longitudinals which are in use on that line; and probably the subject has already attracted the attention of the engineers of that company. But, for the present, attention may be directed to cross sleepers only. For the same reason, the bowl sleepers so largely used by Mr. Livesey, Mr. Batho, and others, and the bowl-shaped cross sleepers now being introduced in India by Mr. A. M. Rendel for flat-bottomed rails, will not here be discussed.

Now the experience in Germany, which by this time is very large, enables us to lay down with confidence the following statements.

Firstly, the corrosion of the sleepers, as to which fears were once expressed, is found to be insignificant. Like the rails, they do not rust so long as the traffic is frequent and regular; and no shortening of their life is to be feared from this cause.

Secondly, the elasticity of the road, as to which doubts have also been expressed, is perfectly satisfactory, no complaints having been heard as to hard running. This will be a matter of little surprise to any one who reflects that iron or steel is in itself a far more elastic material than soft wood, and retains that elasticity immeasurably better under the conditions of daily use.

Thirdly, the connection of the rails to the sleepers has proved a matter of some difficulty, and many ingenious and more or less complicated devices have been brought into use. Satisfactory results have been attained; but this does not concern us at present, because we have to do, not with flat-bottomed, but with double-headed rails. Such rails can only be secured in chairs, and these chairs rest of course on the flat top of the sleeper, and can be bolted or rivetted to it as desired.

Fourthly, the point which in Germany has been found to give most trouble is the tendency of the sleepers to shift endways when laid upon sharp curves. This question is ably discussed in a recent paper by Herr Meyer of Berlin (Railway Organ, 1884, p. 9). He observes that wooden sleepers offer greater resistance than iron ones to such endways motion, for three reasons. In the first place, their weight is greater, and they are therefore less disturbed by sudden shocks. Secondly, their ends have a much larger area to bear against the ballast, in which they are in general deeply embedded. Thirdly, their co-efficient of friction with the ballast is very much higher, not merely because timber is rougher than iron, but because the sharp gravel actually bites into the soft wood, as it cannot do into the hard metal. The iron sleeper bears upon the ballast only at a few points, and is thus easily movable. In addition, the vibration and the churning of water below the sleepers frequently turns the bed into a layer of greasy mud, over which sliding is easy.

In Germany this difficulty has been overcome in two ways; either by bending down the ends of the sleeper, or by rivetting angle-irons or other dividing-plates to its bottom. The first is not very efficient; and the second, though successful, adds materially to the weight and cost. Herr Meyer's own suggestion is to put the sleepers in pairs crossing each other in the form of a St. Andrew's cross. One of them is of course cranked up in the middle, so as to pass over the other, and is rivetted to it. This, though it would no doubt be efficient, involves a decided complication; and in point of fact nothing of the kind seems necessary on English railways. In the discussion above mentioned before the Institution of Civil Engineers, Mr. Wood called attention to the greater length of English as compared with

Continental sleepers (9 feet and 7 feet respectively); and showed two diagrams, reproduced in Figs. 1 and 2. Assuming, as is no doubt the case, that there is always a certain shrinking of the ballast under the rails, an inspection of these diagrams will show at once how much more liable the short sleeper is than the long to such endways shifting. If we investigate what the tendency to such shifting is, we find that supposing a train to pass at a speed so high as 60 miles an hour round a curve of only 10 chains radius, the so-called centrifugal force or outward pressure will not exceed one-third of the weight in motion. When we consider the resistances to be overcome before a sleeper 9 feet long can move endways through the ballast, and also take into account the elevation of the outer rail, it is clear that the co-efficient of resistance will in all ordinary cases be much greater than this. Moreover, English railways have a great advantage in this respect from the much coarser and drier nature of their ballast. No such greasy surface of mud as Herr Meyer describes can be formed in the clean gravel, burnt clay, or broken stone which form the ballast of English railways.

The writer has dwelt particularly upon this point because it is the only one which appears at present to present even a semblance of difficulty; but here, as in all similar cases, experience is the safest guide; and as a matter of fact, a number of Mr. Webb's wrought iron sleepers, which are laid in South Wales on a curve having a radius of only 10 chains (660 feet), and on a gradient of 1 in 40, are reported to show no signs whatever of endways shifting.

The sleepers just mentioned may now be described as forming the most successful instance, and on by far the largest scale, of the application of metal sleepers in this country. They are shown in Figs. 3, 4, and 5, and by the kindness of Mr. Webb, to whom his best thanks are due, the writer is enabled to give full particulars of them. It will be seen that in the cross section the original shape introduced by Vautherin now twenty years ago has been retained, except that the feet are much narrower. This last is no doubt an improvement; the sleeper should not stand, as it were, upon its feet, but bear directly upon the ballast with its sides and top. These sleepers are rolled from Bessemer steel ingots $10\frac{1}{2}$ inches square in a three-high mill, and come out

as bars 60 to 70 feet long, which are afterwards cut into lengths. They are then punched with six holes for the chairs, as shown, the holes being punched from both sides so as to make them slightly tapered in the middle, and so ensure the firmness of the rivets. The chairs are of steel, made from crop-ends of rails and other scrap. This scrap is heated in a mill furnace and rolled into bars; the bars are cut up, whilst hot, into lengths, and each length is placed still hot in a die beneath a steam hammer, and stamped at one blow into the shape of a half-chair. This half-chair is then punched still hot, is put back into the die, and receives a second blow which removes all burrs, &c., and finishes the manufacture. The lining-plate shown between the chair and the sleeper is also rolled out of crop-ends, and sawn up hot to the proper length. It will be seen that it is set in the middle in such a way as to give a firm base to the foot of the rail. Between the chair and lining-plate, and between the latter and the sleeper, are inserted liners of brown paper soaked in tar; these fill up any little interstices, so that no water or dirt can get in between the surfaces, and prevent any possibility of shaking loose or chattering, and bind the whole into one coherent mass. All the parts —chairs, lining-plate, liners, and sleeper—are now fitted together and rivetted up by a Tweddell Hydraulic Rivetter. The moment this is completed, the distance between the rails is absolutely fixed, and so long as the keys are in place, any spreading of the gauge (the source of so many accidents) is rendered impossible.

The keys themselves are of the ordinary kind and shape, and are never found to work loose under any circumstances. This is due partly to the elasticity of the steel chair, which follows the wood in case of any contraction, and continues to grip it tightly; partly to the recess which is formed at the centre of its length, as shown in the section. The wood swells out into this recess where it is not exposed to pressure, and this swelling acts like a feather on the key to prevent any endways motion.

The weight of the whole arrangement is 174 lbs., made up as follows:—

	Lbs.
Sleeper 9 ft. long	124
2 chairs	28
Rivets	5
2 lining-plates	15
2 oak keys	2
Total	174

The weight of a creosoted wooden sleeper of the kind used on the London and North-Western Railway, complete with chairs, spikes and screwed spikes, and felt liners, is 242 lbs.

This difference in weight and bulk might be of considerable importance in the case of shipping sleepers to distant countries.

With regard to cost, Mr. Webb's figures show that a creosoted timber sleeper, complete with chairs, &c., as described, is rather cheaper than the steel sleeper here illustrated, also complete with fittings. It is to be observed, however, that while the price of steel is ever tending downwards, the timber is gradually getting scarcer and dearer, and a very slight change in this respect would bring the two to an equality. Again, it may well be found that a somewhat thinner and therefore cheaper sleeper will answer all requirements. Still it will be better to accept the fact of the excess in cost, and to consider whether there are not certain advantages on the side of the steel sleeper which may make this slightly increased cost a good investment. Some of these advantages may be enumerated as follows :—

1. The life of a timber sleeper, as shown by the extensive researches made in Germany, is a very uncertain quantity, depending on the kind of wood, its seasoning, its pickling, and the conditions of ballast, traffic, climate, &c., to which it is exposed. Probably the extreme limits may be taken at one and at twenty years, and fifteen years will be a very favourable estimate as an average. On the other hand, the iron sleepers laid down on the Bristol and Exeter Railway thirty-one years ago are still in use ; and it does not seem possible to lay down any definite limit to the life of such a system as Mr. Webb's. There are absolutely no parts exposed to wear, and corrosion, as has been already pointed out, does not occur so long as the traffic is frequent ; whilst, if necessary, it can be prevented altogether by dipping the sleeper in any tarry solution, as in fact is done at present.

2. There is no possibility of the gauge spreading, as it often does when the fastenings can cut into the timber sleeper. Moreover the keys, as already mentioned, do not work loose. Hence the labour and cost of maintenance will be very greatly diminished, and with them the risk of accident from the causes just mentioned.

3. In the case of derailment the permanent way is far less

likely to be injured than where the sleepers are of timber, and therefore liable to be cut and crushed by the wheel flanges. In an actual case (mentioned by the writer on a previous occasion) a derailed train ran some distance over a line which was laid at one part with wood and at another with iron sleepers. The result was that all damage done to the latter was repaired, and the line ready for traffic, long before the *débris* of the wooden sleepers had even been cleared away.

4. In severe weather the moisture which has soaked into wooden sleepers freezes, and the road thus becomes hard and inelastic. This is probably the main cause of the well-known fact that breakages of rails, tyres, &c., are much higher in winter than in summer. In the steel sleeper this cannot occur; and although the ballast may freeze beneath it, yet owing to the thinness and conductivity of the metal a very slight rise in the temperature above freezing point will suffice to thaw it again.

5. A last advantage, but as the writer hopes not the least from the point of view of his present audience, is that the use of steel sleepers would give employment to the capital and labour of our own country, now suffering under so severe a depression. On the other hand, there is not a single sleeper upon an English railway which has not been imported from abroad, and of which almost the whole cost has not gone to swell the resources of other and competing nations.

In conclusion, the writer feels it needful to apologise for the necessarily incomplete character of this paper, which has been prepared at very short notice in response to a suggestion kindly made by the President of the Institute. He desires that it should merely be regarded as the starting-valve, so to speak, for a discussion. But, in fact, the case appears to him so strong as to need little advocacy. The problem of metallic sleepers has been thoroughly mastered in Germany, and worked out with all the exhaustive care and skill for which the engineers of that country are celebrated; whilst its solution, in the particular form demanded by English conditions, appears to the writer to have been satisfactorily achieved by Mr. Webb. Nor can it be said that this solution is a theoretical one merely. Some 40,000 of these sleepers are now in use, and some of them have been down for a period of three years. They may

fairly claim, therefore, to have answered the test of practical work. It remains to ask why their introduction is still so slow and so doubtful. Is the answer to be found in the remark made by an eminent engineer during a former discussion, in which he congratulated English railway companies on the caution and slowness of their advisers, whereby they had avoided the failures which in many cases had been experienced on the Continent? If English engineers have thus begun to take pride and to assume credit for being in the rear of progress, instead of in the van, it is not to be wondered at if the manufactures of England are threatened with ruin, and our industrial supremacy with defeat. Mr. Webb has, however, already falsified the prophecy then made, that no engineer of sound judgment would ever intrust to iron sleepers the carrying of such a traffic as that of the London and North-Western Railway; and the writer has been glad to learn within the last few days that the engineers of other lines are beginning to follow in the same track. He hopes, therefore, to see the time, before many years are over, when the importation of timber into England for the making of sleepers will be looked back upon as a curious delusion of the past, and useful work be found for our steelworks at home.

DISCUSSION.

Mr. W. R. Browne said since the paper was written he had had the opportunity, through the kindness of Mr. Matthews of the North London Railway, of inspecting a set of fifty steel sleepers of Mr. Jockstype's laid on their main line between Hackney and Dalston. These sleepers had been down fully three years, and they were exposed to what was, at any rate, not far short of the heaviest traffic in the world. Scarcely five minutes ever passed from one twenty-fours to another in which a train did not pass over those sleepers; and it was not merely passenger traffic, but there was also a heavy goods traffic; so that their service might be looked upon as equivalent to a considerable number of years upon an ordinary line. The report of these sleepers, he could only say, was thoroughly satisfactory. With regard to corrosion, there was none visible. As regarded elasticity, that to the eye, looking at a train passing over it, was obviously satisfactory. He subsequently passed over it in a train running at a fair speed, and he found it impossible to tell either when they passed from wooden to iron sleepers, or from iron to wooden again. Two or three rivets had been found to be slightly loose, but that was the extent of damage of any kind found in the permanent way. He catechised the foreman platelayer on the subject, and was told the iron sleepers were somewhat more ready to sink into the ballast than the corresponding wooden sleepers. Of course, with that enormous traffic, whatever sleeper was used, there was always a certain amount of giving way, which had to be watched and set right again; but the foreman said, on the other hand, that an iron sleeper was considerably easier to pack up again and get into level, because it was not so deeply buried in the ballast; so that the one thing counterbalanced the other. He had no other complaint to make of the road whatever. When they considered that these were some of the first sleepers of the kind made, and that the conditions under which they were put down and tried were very severe, it must be admitted that this formed a very satisfactory record.

As Mr. Webb was not able to be present, perhaps he might be

allowed to read extracts from one or two letters he had sent him on this subject. The first was from M. Gustave, one of the Commission of Belgian Engineers sent over to examine the permanent way of England, and it contained a report on Mr. Webb's new sleepers on the North London Railway :—

"Brussels, *February* 20, 1884.

"Agreeably with the desire expressed by you in the course of the conversation we had in your office at Crewe, the other day, I take this early opportunity of informing you that your system of permanent way appears to us to be in all respects *very good.* It was clearly demonstrated to us that, on the passing of trains, the sleepers did not give way at all; that the keys held firmly; that the rails presented throughout perfectly straight lines without undulations—in short, that your type of road gave most *excellent* results. At the same time permit me to remark, that we have taken out several keys, but have not discovered the swelling which you mentioned, and which, according to the information you were so good as to give us, should fill the hollow left in the centre of the chairs, though perhaps this is owing to the nature of the wood.

"I should be very grateful if you would procure for me a copy of the photographs of your permanent way—those which you showed us belonging to our management. I purpose giving a descriptive paragraph of your system of road in the general 'Review of the Railways of Paris,' and it will be very useful for this purpose to have these photographs."

Then Mr. Webb, in replying on the question of the keys, said:—

"Crewe, *February* 27, 1884.

"Dear Sir,—I am obliged for yours of the 20th inst., giving me the results of your inspection of my system of steel permanent way. With regard to your remarks about the wooden key not swelling into the recess inside the chair bracket, of course the amount it swells is not very great, but quite sufficient to prevent the key backing; and I presume that those you saw were driven out on purpose for your inspection, and the very fact of driving them out would cause the swelling in the centre to be again compressed. If your Government decide to try my system in Belgium, I shall be glad if you would kindly favour me with the result of the working of the sleepers when they have been down some little time.—Yours faithfully,

"F. W. Webb."

Mr. Webb had also sent him the following letter from Mr. William Bradford, the engineer for the South Wales division of the London and North-Western Railway:—

"BUILTH ROAD, *April* 28, 1884.

"*Road laid with Steel Sleepers.*

"DEAR SIR,—Referring to conversation last week, I have a length of 600 yards, which was laid in May last, upon the up-road of the Merthyr, Tredegar, and Abergavenny line, near Govilon Station.

"The line, for the greater part of this distance, is on a 10-chains curve, and the whole of it is on a descending gradent of 1 in 38.

"About fifty trains a day pass over it, the greater number of which consist of goods and minerals, worked by heavy tank engines. Notwithstanding these heavy weights, and the brakes of waggons always being pinned down, it has not been in any need of repair since having been laid in, but has kept in line and curve remarkably well.

"The ballast is broken slag, but as the road has been laid in as yet for a comparatively short period, I am unable to give you any figures as to the difference in cost of maintenance between this and our ordinary road with wooden transverse sleepers; but I don't think this road in years to come *will cost more in repairs than our present road;* and when it comes to a renewal at the end of say twelve years, I anticipate there will be a considerable saving, because, instead of having to provide new *sleepers*, *chairs*, and *fastenings*, new rails only will be required, or a saving of about £625 per mile.—Yours faithfully,

"WM. BRADFORD."

Mr. Webb had supplied a list of all the places on the North-Western Railway on which his sleepers were laid down, beginning in 1880 on the Chester and Holyhead line. The total number laid was 20,000, and there were 12,000 more in order. The list was as follows:—

In 1880—

On the Crewe and Chester line, and on the Chester and Holyhead line.

In 1882—

Between Crewe and Warrington; between Crewe and Manchester between Crewe and Stafford; and between Stockport and Buxton.

In 1883—

Between Rugby and Birmingham; between Northampton and Market Harborough; between Liverpool and Manchester; North Union line; between Lancaster and Carlisle; between Crewe and Warrington; between Chester and Holyhead; and on the Merthyr, Tredegar, and Abergavenny line.

This year (1884)—

On the Crewe and Shrewsbury line; on the Chester and Holyhead line; on the Manchester and Leeds line; on the Manchester and Stockport line; and on the Liverpool and Manchester line.

Mr. DANIEL MACNEE (Westminster) said he could contradict Mr. Browne's statement that "there is not a single sleeper upon an English railway which has not been imported from abroad." Mr. Macnee had laid down a great many wrought iron and steel sleepers on railways in both England and Scotland. They were in use on the Great Eastern, Great Northern, Caledonian, and other railways. All the sleepers he had laid down had closed ends, and were stamped out of iron or steel plates, in the form of a trough, and they had all been manufactured in this country by the Anderston Foundry Company. He had been told by the authorities of the railway companies who were using the so-called Webb's or Wood's sleepers with open ends, that they gave much dissatisfaction, as it was impossible to keep them from travelling sideways.*

Mr. CHARLES WOOD said, as he was one of the first to call the attention of the ironmasters in England to the employment of iron and steel sleepers on the Continent, he had followed with considerable interest the steady development of the whole question,

* Mr. Webb, in reply to this statement, desires to give publicity to a letter from the engineer of the North London Railway, dated May 8, 1884, in which the writer states to Mr. Webb that "the iron and steel sleepers on this line which were supplied by you have not failed in any respect, and we have no intention of taking them up. The only difference the platelayers have found between the iron and wooden sleepers is that the former have required a little more packing than the latter."

and a good deal of credit was due to Mr. Webb for the part he had taken to prove that steel was a suitable material for the purpose. In the few remarks he had to make, he would follow as nearly as possible Mr. Browne's paper. The first point that came under his notice was the question of corrosion, and Mr. Browne had very rightly stated that, in a paper which he (Mr. Wood) had previously read, he gave instances of iron sleepers which had been laid on the Great Western Railway for a period of thirty-two years. He exhibited in that room, before the Institution of Civil Engineers, a section of one of those sleepers in which the corrosion had been practically *nil ;* but wherever there was a bolt passing through there had been chattering, and the head of the bolt in some cases had eaten its way through the thickness of the sleeper, showing clearly that where a loose rivet or bolt was used chattering commenced immediately, and soon ate completely through. He distinctly stated in that paper, and showed by his models and drawings, that he considered that neither nuts nor rivets should, if possible, be used. Mr. Browne had mentioned that the only fault that could be found with the sleepers of Mr. Webb's design that were laid upon the lines near London was that "some of the rivets had worked loose" after they had been down so short a period. That really struck at the root of the whole thing. He did not believe that the brown paper cushion, and any amount o hydraulic pressure on those rivets, under a traffic similar to that of a railway, would hold them tight, and the moment the water got in between the rivet and the sleeper, a vibration commenced, the water became acid, and corrosion immediately set in ; and wher once that happened, in the course of a very few months they would find it commence to chatter, and eventually eat itself int the sleeper. He was speaking from actual experience of a goo many years, and of a good many observations, and had he been little better prepared he would have produced samples which lay i his office at the present moment to illustrate his meaning. He ha never yet heard it explained why a sleeper or rail under traffic di not corrode, and why a sleeper or rail lying beside a railwa did corrode considerably. It was a problem that he had neve heard answered, and perhaps he could not fully grapple with th question himself. At one time he had partly attributed it to th rails being magnetised. That the constant passing of a train i

one direction set up magnetism, and that magnetic oxide did to some extent preserve iron and steel there was now no doubt. He did not now think, however, that there was very much value to be attached to this. That rails were magnetised considerably was no doubt the fact; it only needed testing to prove it. For instance, if they took some steel filings and placed them upon the rail, they would see them standing straight up. He looked upon the question more in this light, that upon rails or sleepers in use a coating of rust was not allowed to gather; whilst, on the contrary, if a rail or a sleeper lay perfectly still, a scale formed, moisture got underneath that scale, the scale prevented evaporation, and so it went on corroding. He had seen, only last week, a stack of rails that had been lying about eighteen months at the Middlesbrough dock, for some reason or other, and there was very nearly three-sixteenths of an inch of scale upon them. If they picked that scale off in almost any weather, they would find dampness underneath. In the case of a rail over which traffic was continually passing, scale was not allowed to collect; every train that passed dashed the water or any particle of dust away and left the surface free, and any moisture that was left immediately evaporated. That, he considered, was one of the chief reasons why iron and steel sleepers did not corrode when in use. A good deal of discussion had taken place upon turning down the ends of sleepers. He had studied this question also, and, so far as he was concerned, he had satisfied himself that there was no necessity for it whatsoever. If they would allow him, he would explain why. Mr. Browne produced a diagram taken from the paper he had read before the Institution of Civil Engineers in that room, representing a sleeper made after the Continental style. Mr. Wood copied that on the black-board, perhaps slightly exaggerating it. It was a well-known fact, in the first instance, that the Continental sleepers were very light; few exceeded eighty or ninety pounds in weight, and they were also only from 9 to 10 inches wide, and about 7 or 7·6 inches long. A train passing over such a sleeper pressed it into the ballast every time, and so disturbed the ballast at the end; and there was such a disturbance going on that Continental engineers all said it was the shifting of the ballast. It was nothing of the sort; it was the compression of the sleeper that disturbed the ballast, and the continual rocking of the sleeper

that shifted the ballast. That could be easily proved, because any person who saw a train running over the short sleepers very quickly would see the ballast being pitched away. That clearly showed that the closed end was perfectly useless. Upon the other diagram they had the long sleeper, as employed by Mr. Webb and himself. The zone of disturbance in this case was shown to be removed. When a train passed, it slightly depressed the ballast underneath, and consequently the sleeper was there hollow; the zone of disturbance was shifted, the sleeper laid solid under the two outside ends, and they would see that the sleeper got three bearings instead of one. In one case the bearing was only in the centre between the rails, and in consequence a rocking motion was set up, and the line was very unstable and unsatisfactory. In the other case, having three bearings instead of one, the full length of the sleeper did its work; the line was kept perfectly steady, and was in every way more satisfactory. If they would examine Mr. Webb's sleeper, or those that remained under traffic on the North-Eastern Railway, they would see that with those long sleepers no disturbance would be found at the ends.

Mr. Browne had said that the traffic upon the North London Railway was perhaps the heaviest in the world, but he thought there were few people who would deny that the traffic on the North-Eastern, where there were mineral trains of 400 tons each passing every five minutes, up to 250 trains a day, constituted a much heavier traffic than was to be found upon any London line. In going round the curves, there was not the slightest disturbance of ballast whatever, and therefore he thought that was a full proof that turned-down ends were perfectly useless for retaining the ballast. He had also shown that where they had a sleeper that was bent to give the tilt to the rail, the end of the sleeper, as would be seen on the diagram, was elevated equal to about $1\frac{1}{2}$ to 2 inches. That elevation, pushing against the ballast, prevented end-shifting, and was equal to any little bit of end they might put on; and it was a further proof that if sleepers were only made long and strong enough, turned-down ends were useless. The sleepers laid on the North-Eastern were the first laid in England, and they had nearly all been taken up recently. There were two miles of them; they were down between

five and six years; and, as he had said, they were laid upon a very sharp curve, and had carried about sixty million tons of traffic and worn out two sets of rails. They were rolled out of puddled bars. When the load came on the short sleepers, the top web was in tension, because the two ends were depressed. When the sleeper was made longer, as shown in the diagram, it would be seen that the load came on the bottom web; the action was entirely reversed; there was no longer a tension on the top, but a tension on the bottom web, and compression on the top web. Those that were laid on the North-Eastern line, rolled out of puddled bars, were not sufficiently strong to stand the tension on the bottom web, and several of them broke, and the ends—as the platelayers called it—" cocked up." They never broke across the top or through the holes; they simply bent up. Mr. Webb had had the good fortune to be able to make all his sleepers of steel, and the difference between common iron and steel was, that the latter was four or five times as strong. This had been sufficient to overcome any little difficulty as to breaking. Since those were laid on the North-Eastern, steel sleepers could be bought at less than those rolled out of puddled bars; and of course there was also the elasticity of the steel sleepers to be taken into account, as there was not much elasticity in puddled bars.

Mr. Browne had mentioned that Mr. Webb's sleepers had cost threepence each beyond the cost of timber sleepers. If the cost was only threepence per sleeper (" above that of the ordinary timber and cast iron chairs"), with all the extra work of manufacturing and rivetting the chairs upon the sleeper—if that was the only difference, comparing the cost of double-headed rails and flat-bottomed rails, it would sink into insignificance, because the simplicity of the clip he employed would save, not threepence, but he might say more nearly one shilling per sleeper. There were no bolts, or nuts, or rivets to chatter themselves to pieces; the wood key took the slack always up. It was stated in the paper that twenty thousand sleepers had been laid by Mr. Webb. That certainly did not seem a very large quantity; and the paper seemed to indicate that there had been little or no interest taken in the question by our Colonial engineers. He thought he could show that since he had the honour of reading his papers before the Iron and Steel Institute and the Institution of Civil Engineers

considerable progress had been made. To his own knowledge within the last two years there had been not less than forty thousand tons of steel sleepers manufactured in England. That certainly could not be said four years ago; such a thing was then unheard of. He had made himself, with the orders at present on hand, one hundred and eleven thousand sleepers, which had gone all over the world, and he had never heard a single complaint of any sort. There was no doubt that the cheapness of his fastening, and dispensing with the turned-down ends, were the chief causes why the sleepers were so much liked, and he believed they would continue to be liked. He did not pretend to go in for the double-headed rails; he had always said that that required complication, to which he did not care to trust himself. He might also mention that on the Continent, and in the Colonies, the flat-bottomed rail was almost invariably employed. On the Continent, nearly all the lines were originally made simply by using the Vignolle rails, spiking down upon timber. As traffic increased those sleepers began to give way, the lines spread open, and accidents occurred, causing them to put steel sleepers underneath to keep the line to gauge. But that was not all. In some papers read before the Institution of Civil Engineers, some very exhaustive experiments were described, and it had been clearly demonstrated that if they compared the double-headed and the flat-bottomed rails of the same weight, the latter would be found not only much stronger, but they got extra stability. That was easily understood, because the bottom of the rail formed the bottom web of a girder; it was spread out, and therefore there was very good sense in the constant employment of the flat-bottomed rail, not only on the Continent, but in the Colonies as well. That was also so, because the flat-bottomed rail gave a better bearing surface upon the sleepers, and could at any moment be laid either upon a wood or a steel sleeper, which could not be done with a double or bull-headed rail. Another point which had not been mentioned, and which was of some importance, was that the sleepers which had been lately taken up from the North-Eastern Railway had been sold, after nearly six years' employment, at half their cost, as old iron. Considering that old timber was really valueless, except for firewood, he thought that the cost of the old iron ought to go considerably

to the credit of steel sleepers. He had it in writing, from more than one engineer, that the cost of laying steel sleepers was about sixpence per yard less for labour than if they were laid in wood and spiked down. That also was an item which should be taken into consideration. There was—as Mr. Browne had mentioned—the question of ballast. The sleepers were certainly very easily packed, but the ballast required rather more attention. It wanted to be well drained, so that there was no collection or churning of water under the bottom. There was only one other point to which he wished to direct attention. A good deal had been said in favour of iron and steel sleepers, but nothing had been said as to why English railways so persistently adhered to the present system of wood sleepers and iron chairs. He had seen in that room, two nights ago, timber sleepers that had been laid on various railways in England, and he had also seen some creosoted sleepers which had been down over thirty years, and when they were taken off the main line they were used again in sidings, and were perfectly sound. One of the chief reasons why those old sleepers gave way was the small base and lightness of the rail chairs. They ate under the load into the sleepers. During the last few years sleepers had been cut out of half baulks; they were mostly creosoted, and the base of the chair had been increased from 11 inches $\times$ 4 to about 14 $\times$ 8 inches. The base of the chair upon the timber sleepers was double those laid thirty years ago, and had given English railways such a magnificent road that there was nothing like it in the world. Was it therefore to be wondered at that English engineers were conservative on that point? Going from England to India, and to any of the Colonies, the case was completely reversed. An eminent engineer had told him, only a few months ago, that there was a difference in the quality of the creosote now. They extracted bye-products from it, and it had lost its preserving properties; so that instead of laying timber sleepers of the best quality, which in India would last for fifteen years, they could not now be depended upon beyond an average of four or four and a half years. India, therefore, was undoubtedly the place for steel sleepers. Comparing the cost of steel sleepers and cast iron pot sleepers, he had shown, before the Institution of Civil Engineers, in the case of the 5 feet 6 inch gauge that the economy was £450 per mile;

and in the case of the metre gauge it was nearly £90 per mile. But since he had read that paper, steel had gone down forty shillings per ton, and the consequence was that he could now supply steel sleepers with an additional economy of £50 per mile, at the very least, for the metre gauge, and another £100 for the broad gauges of England and India.

Mr. Jeremiah Head said he had had frequent opportunities of walking up and down that part of the North-Eastern Railway where Mr. Wood's sleepers had been in use during the last five years, and he thought it might be of some slight interest for him to state what he had observed. Notwithstanding that Mr. Wood said that his sleepers were only puddled bars, and therefore could not be expected to be elastic, they were very elastic indeed. He had watched the passage of many heavy trains over them, and could plainly see, not only that the rails assumed a wave-like form, but that there was a similar and distinct motion in the sleepers themselves, every time the pressure came upon them. If Mr. Wood intended his piece of asphalted paper to assist elasticity in any way, he could not see that it was necessary, because there was abundant elasticity in the sleeper itself, whether made of iron or of steel. He could really see no difference in elastic movement, whether the way was laid upon iron sleepers or upon wooden ones ; the one seemed to be just as elastic as the other. With regard to corrosion, he had often searched for evidences of that, but he could see no corrosion whatever on the sleepers, except, as Mr. Wood had pointed out, where there were two surfaces in contact. Between the rail and the sleeper (in that case they were flanged rails) there was generally corrosion as well as wear ; also wherever any fastenings occurred there was always a tendency to the harbouring of water, and, consequently, of rust. That brought them to this point, that of course the part of the sleeper immediately below the rail was weakest, for three reasons. Firstly, there alone was any liability to rust; secondly, there alone was there any wear; and, thirdly, there alone was the section of the sleeper interfered with by making holes. Mr. Webb apparently recognised those points thoroughly, and counteracted them by putting a separate sole-piece between the sleeper and the rail or chair. Mr. Wood's sleeper was defective in that respect.

He would suggest whether it would not be an improvement in Mr. Webb's sleeper if he should make his sole-piece a little longer than it was at present on each side of the rivets. If any sleeper were to give way, it would, of course, be through the rivet holes, and if he was to carry the sole-piece a little farther, right and left of the rivets, he would force it to give way, if at all, farther from the holes, and therefore in a stronger place. With regard to the length of sleepers, he quite agreed with Mr. Wood. It was quite evident that the object of the sleeper was to carry the weight of a short section of the line and all that passed over it. Half the sleeper supported the weight of one chair and the other half on the other. Now, why they should decide to make the length between the centre of the sleeper and the chair longer than the length between the chair and the outer end of the sleeper he could not imagine. Theoretically they ought to be equal, so as to give equal support on each side of the chair; but if anything, he should have thought it would have been better to give a little extra length on the outside in order to assist in preserving the tilt of the rail when severely pressed upon, to make it throw it inwards rather than outwards. He was sorry that other kinds of sleepers had been rather too easily dismissed in the paper—for instance, the Livesey sleeper, which was dished out of the plate, and in which there were closed ends. That seemed one of the most popular sleepers of the present day, and it entirely avoided any danger of sliding on the ballast. He might say, however, that when inspecting Mr. Wood's sleepers on the line, he had occasionally questioned the platelayers whose business it was to look after them, and he inquired of them whether they had observed anything like a slipping of the sleepers end-ways on that part of the line which was on a curve. They told him that they never had, in any case. In their view, the principal drawback was that it was rather more difficult to ballast iron sleepers than wooden ones; that to get the ballast underneath the trough-like section, and to get it thoroughly and solidly packed, they found more difficulty. He would only add that this question must necessarily be of the greatest possible interest to all connected with the iron or steel industries, inasmuch as if foreign wooden sleepers could only be replaced by English-made iron or steel, it would mean a trade for them almost as large as the rail trade;

and really it was very difficult to see why it did not make greater progress than it had done.

Mr. C. Markham said it was to be regretted that in discussing this subject the question had not arisen whether sleepers ought not to be entirely abandoned. He was inclined to think the Barlow rail would ultimately be generally adopted, now that it could be made in steel. About thirty years ago the Midland Company laid several miles of their permanent way between Derby and Leeds with the Barlow rail, weighing 128 pounds to the yard, and he had a very vivid recollection that for a considerable time the Barlow rails formed the best piece of permanent way on the Midland. Finding the experiment appeared to be successful, the late Mr. Brunel determined to adopt the Barlow rail, and Mr. Barlow and Mr. Brunel reduced the weight to 90 pounds per yard. A considerable length of those rails was laid on the Midland, and it was adopted by Mr. Brunel over a large section of the South Wales line, from Gloucester. The Barlow rails, however, rapidly failed in consequence of their being made in soft iron; both heavy and light rails rapidly laminated, and they were gradually removed, and the system abandoned. He was well aware that there was a mechanical defect in the mode of connecting the ends of these rails. He took a considerable interest in the success of the Barlow rail, and he had never ceased to advocate its adoption. The Barlow rails that were removed from the main line were used for sidings, and many of them were now in use, having been employed for that purpose for upwards of twenty-five years. He was of opinion that the Barlow rail, if made to weigh about 130 pounds per yard, with proper joints and cross-ties, would supersede the present permanent way. In regard to what was said about corrosion, they all knew that in certain ballasts rails and chairs corroded with marvellous rapidity. In the Clay Cross tunnel, and in the neighbourhood of Sheffield, the line had been laid with ash ballast, and the corrosion and waste had been very remarkable; but of late years the Midland Company had adopted a system of not allowing the ballast to be placed above the level of the sleepers, so as to keep all the iron work out of contact with the ballast. With regard to the wrought iron or steel sleepers, he was very much inclined

to think that the rivetting of the chairs upon the sleepers would not be found satisfactory, as they would work loose from the constant vibration. He strongly believed that the Barlow rail would be the rail of the future, and now that Mr. Richards and other steelmakers could produce a good steel rail that would not crush and wear away, he thought there was a great future before it.

Mr. Fisher Smith wished to ask Mr. Browne if he could tell them whether Mr. Webb had ever tried the plain plate. For a great number of years he had used sleepers. They began with the pig-trough sleeper, then with *pan chairs*,* then with something else. The last thing they had used had been the plain plate made in the cheapest way, with the chair bolted upon it. It was a wrought iron plate. It possessed certain advantages. It was very easy to pack, and did not collect damp or anything of that sort. He did not know if Mr. Browne could tell whether it had ever been tried.

Mr. Wood said he could answer that question. In Spain, at the present moment, he might say there were several hundreds of miles laid with perfectly plain plate sleepers made after De Bergue's old system. At present, he was making 1200 tons for an extension of the same railway—perfectly plain square plates upon the bottom, and fastened by a tie-bar. When he was apprenticed, thirty years ago, he helped Mr. Allan Ransome to carry out experiments by a falling weight upon those same sleepers. They had been in use upon Spanish railways from that time up to the present, and they were, year by year, increasing the quantities supplied. It therefore followed that it was not necessary to have a trough form at all for stability in a sleeper. The only reason for applying two rolled sleepers was that they got two sides of a girder for strength. In the cast iron one, the plate itself had sufficient strength to stand the strain. That was also a further proof that turn-down ends were useless. It was simply bearing surface that was wanted. The weakness of the Barlow rail was in the joints and the fastenings of the fishes; those gave

* Pan chairs are cast upon a "pan" something like a tea-tray and connected by a wrought iron rod.

way and caused a wave-like motion upon the railway in the same way as upon the longitudinal sleepers on the Continent, and therefore he considered that that was one of the chief sources of weakness, and the reason why Barlow rails would never be used again.

Mr. Edward Williams said that one cause of the failure of the Barlow rail had not been generally understood. The form of the rail was such that it was not easy to prevent the layers of iron constituting the pile from travelling over each other in the operation of rolling. He believed it to be impossible to convert pieces of iron placed one on the other into a solid mass by anything short of melting. After the most perfect welding otherwise, the layers remained distinct—separable either by wear and tear, or by other mechanical means. In the case of a rail, it was only a question of time when the top must peel off. The Barlow rail could only be rolled head downwards, and the travel of the tongue of the top roll forming the inside of the head was so very much in excess of that of the bottom roll, which formed the wearing surface of the head, that the layers of iron frequently slid over each other, and so made bad welds. All rails of the bridge section had this fault to a much greater extent than the double-headed and flanged sections, all of which were rolled on their sides, and not head downwards. That objection disappeared now that rails were made from solid steel ingots, and he believed that the Barlow rail so made would wear as well as any other. The question of how far the section was suitable or unsuitable for permanent way without sleepers was for the Institution of Civil Engineers to decide; he could give no opinion.

The President said they were much indebted to Mr. Browne for having had the kindness to prepare that paper, especially on the very short notice that was given him. He thought the subject was one of so much importance to manufacturers of iron and steel that it was desirable it should be discussed at that meeting. No doubt there would be other contributions on the same subject at future meetings, as further experience was acquired, and it was satisfactory to have heard from Mr. Wood that although not much progress had been made in the laying

of metallic sleepers in this country, the case was different in the Colonies. They were aware, no doubt, that a Committee of the House of Commons was at that moment considering the question of more rapid progress in regard to the construction of railways in India. This was one of the countries in which this question of metal *versus* wood was certainly of very great importance. With respect to the paper itself, he would only remark, that he was not one of those who joined in the cry against English engineers and English manufacturers as being behind the world. The Report of the Commission on Technical Instruction was now in the press, and he believed that when it came out it would be found to be satisfactory in this sense, that they were not in any respect so far behind the world, either as regarded knowledge, the acquisition of knowledge, or the application of knowledge, as was sometimes rashly asserted. Mr. Browne had done well perhaps to administer a stimulant to their engineers. It would never do any harm, but at the same time he thought they ought to acknowledge that they were still, as they always had been—perhaps excepting the Americans—the nation which was more ready to take up new ideas and new inventions than any other country in the world. He was sure they would join with him in a hearty vote of thanks to the author of the paper.

A vote of thanks having been heartily accorded,

Mr. Walter Browne, in reply, said with regard to the obser-servations of Mr. Macnee, that he did not of course mean to imply that the North London Railway was the only railway except the North-Eastern and North-Western on which iron sleepers were laid. He had mentioned it because it was a railway which he had had the opportunity of visiting. With reference to what Mr. Macnee had said as to the other railways—the Great Northern and the Great Eastern—where the sleepers were made with closed ends, he thought that that question had been sufficiently considered and disposed of in the paper and in the discussion, and that under English conditions, at any rate, those closed ends were not found practically to be necessary. He need not follow Mr. Wood through the whole of the speech with which he had favoured them. With regard to corrosion, the fact that rails

and sleepers under traffic did not corrode was sufficient for him at any rate as an engineer. Scientifically, however, the question was one of considerable interest, and he thought it probable Mr. Wood had thrown some light upon it. No doubt it was the vibration due to the traffic which in some way prevented the process of oxidization going on, as it did go on when a piece of iron was left at rest under the influence of the weather. Mr. Wood objected to the fastening of the rails by rivets, and said that they would get loose. He supposed it was impossible by any human means to fasten two pieces of metal together in such a way that it was absolutely impossible for them to get loose, and he could not think that Mr. Wood's own mode of fastening, ingenious as it was, could be an exception to the rule. Certainly in Germany great difficulty had been found in preventing the cutting into the iron of the clips, cotters, and so forth which were used in order to unite the iron sleepers with the rails. For himself, he should be inclined to pin his faith to rivets, and of proper size, put into holes made taper both ways, as he had described, and thoroughly rivetted with sufficient pressure by hydraulic or other means, as much as upon any other mode of fastening that could be devised; and he thought that most engineers would be inclined to agree with that view. Of course the rivetting up was done in the shop; the rail, the sleeper, the chair, and so on were all rivetted up in the shop in the ordinary manner by a hydraulic rivetter, leaving nothing to be done on the ground except merely putting the rails in place and driving up the chairs, so that the work could be done in the most complete and satisfactory manner. Mr. Wood observed (what was no doubt true in the case of a long sleeper of the kind he had sketched) that it was the upper side of the sleeper that was in tension and the lower part in compression. That applied to Mr. Head's subsequent objection as to the possibility of the sleeper giving way through the rivet holes. No doubt the strain on the upper part, as the train passed over, was a strain of compression, and if the rivet holes were properly filled, the rivets would be able to take their fair share of that strain. But practically he considered that Mr. Webb's sleeper, at all events, was amply strong enough to remove all fear of fracture, and that the question need not be considered any more than it would be considered in the case of a bridge over which a train

passed. The sleeper was necessarily made stronger than there would be any need to have it for the mere chance of its breaking under traffic.

He did not wish to discuss Mr. Wood's system, and, as he had mentioned in the paper, he had abstained from discussing many other systems which had been proposed. He thought that enough had been said on those in former papers, and his object was to bring forward one side of the question which, in his opinion, had not received sufficient attention, namely, the application of steel sleepers to the carrying of double-headed rails; because, whether rightly or wrongly, double-headed rails were the system that had practically found favour amongst English engineers. If ever steel sleepers came, as he believed they would come, to be substituted on English railways for wood, they must be sleepers that could be adapted to the double-headed rail. No English engineer would change his whole system of rails and sleepers at one blow.

Nor had he wished to imply that no progress had been made in the use of steel sleepers in the colonies; he had confined himself to England. Steel sleepers had been used in the colonies for many years, and their use, he was happy to think, was steadily extending. He was glad to hear that Mr. Wood had done so much towards introducing his own sleeper, and he hoped that the other kinds of sleepers adapted to flat-bottomed rails would be similarly successful. Of course there was the advantage pointed out by Mr. Wood, that the value of the old iron sleeper was considerably greater than that of the old wooden sleeper; but he did not dwell upon that, because he saw no reason why steel sleepers should ever get old and want to be renewed. It was much the same as in the case of a bridge. The value of an iron bridge when it became scrap iron would be greater than the value of an old timber bridge; but people did not look forward to iron bridges becoming scrap, and there was no reason why they should look forward to steel sleepers coming to that condition. They might regard a steel sleeper road as a succession of steel bridges over which a line was laid.

Mr. Wood's statement as to the saving of 6d. a yard in laying had surprised him, and he should be glad to know whether it was accurate, because it would not merely counterbalance

the slight difference at present existing between the cost of metal and wood, but would even make the steel, as laid, cheaper than the wooden sleeper, which was an important point to establish. The use of the paper liners in Mr. Webb's system, to which attention had been called by Mr. Head, was not at all for the purpose of promoting elasticity. Steel was one of the most elastic materials in the world, and wanted nothing to assist its elasticity. The use of the liners was to prevent the possibility of moisture getting in between the surfaces in contact, and so to prevent the possibility of that very corrosion which Mr. Head had mentioned as having noticed in the case of some of Mr. Wood's sleepers.

He wished to say one word more with regard to the Barlow rail. It had given him pleasure to hear the merits of the Barlow rail once more discussed. Some years ago, when considering the question of permanent way somewhat thoroughly, he went over the whole story of the Barlow rail, and satisfied himself that the only cause of its failure was the fact that, owing to its peculiar section, if it was to be rolled at all, the iron had to be made so exceedingly soft that the head of the rail would not stand the abrasion and wear of the traffic; and it struck him then that that would be overcome if the rail could be rolled out of a steel ingot, and that it was a pity that a system which had so great an advantage in the way of simplicity should not be tried once more. The lucid explanation which Mr. Edward Williams had given of the causes of the previous failure, and his opinion that they would be removed by the substitution of steel, were of great importance; and he hoped that they would lead some engineers once more to try this, the simplest of all possible systems of permanent way.

He would only say, in conclusion, while thanking the members present for the way in which they had received his paper, that he hoped it would not be understood as if he wished to complain of English engineers as a whole. As an English engineer himself, he had no wish to foul his own nest. He thought, indeed, that in that particular instance of improved permanent way, it might be said that they were somewhat behind the times, and it was on that point he wished to give emphasis. There were many other points, however, on which that could not be said, and he hoped

that the reproach to which he had alluded, if it was a reproach, would before long be wiped away.

Mr. Markham desired to add that the top of the Barlow rail was made of very soft iron, and in the course of a few months it began to give way from the rolling weight that passed over it.

Mr. Browne asked if it was not the case that soft iron had to be used for the flanges of the rail, and that practically, as a matter of fact, the head got to be made of soft iron also ?

The next paper read was :—

THE BEHAVIOUR OF ARMOUR OF DIFFERENT KINDS UNDER FIRE.

By Captain C. ORDE BROWNE, Lecturer on Armour at Woolwich.

The object of this paper is to notice briefly the features in recent experiments which bring out the characteristic behaviour of the principal kinds of armour under the impact of shot, and then to point out the necessity for recognising that the mechanical conditions of one case may be so entirely different from those of another as to call for different qualities in the shot, and a totally different system of calculating effects. The importance of this question will be apparent if it is borne in mind that there are four principal kinds of armour employed by European powers. The natural tendency is for us to test our own shot and armour against one another. The important matter, however, is to know the behaviour of our shot against the particular kind of armour that our enemy may have, not against our own. It appears, perhaps, like killing two birds with one stone if we prove our shot against our own armour. The advantage of such an achievement, however, is lost if one bird is a wrong one, and this may in a certain measure be the case if we continually follow the above course in the face of the adoption of armour by foreign powers differing widely from our own in its nature.

The four kinds of armour to which I refer are as follows:—

1. *Wrought iron.*
2. *Wrought iron with a steel face* (termed *compound* armour).
3. *Solid steel;* and,
4. *Chilled cast iron.*

I will first specify, as far as I am able, the characteristic behaviour of each under impact, in order that, when I come to them, you may see how far the experiments I notice bear out what is said; and I would observe that these experiments are simply the most important recent ones, and cannot be said to be specially selected.

1. *Wrought iron* yields locally; it is punched or perforated, a clean hole being made in it. The rest of the target hardly suffers appreciably, except close to the point of impact. The entire shield, including bolts, is generally capable of resisting any subsequent blow as stoutly as it resisted the first one. Effect here must be obviously produced by the bare power of perforation of each round taken singly. Partial penetration is practically useless, however often it may be repeated. The shot experiences but little resistance as its point enters, and hence it is well enclosed and supported round its head before the full strain comes on it. Hardness and rigidity of metal in the projectile here tell to the greatest extent, and tenacity to the least. Need I add that these conditions have favoured the use of Palliser's chilled iron shot with sharp points? The plate yields at the back opposite to the point of impact by tearing in a cross or star line, letting the point of the shot through the centre.

2. *Steel-faced wrought iron*, Cammell's, made on Wilson's patent, or Brown's on Ellis's patent. Here the steel face, which constitutes about one-third of the thickness of the plate, is a harder class of steel than is generally supposed,* and resists the point of the shot abruptly, and severely tries the tenacity of its metal. It is seldom, indeed, that a projectile holds together under these conditions; there is a mechanical force acting something like the outward thrust on the sides of an arch, and the shot sets up, or more commonly breaks to pieces, leaving but little metal lodged in the plate. The plate yields mainly by cracking in radiating lines from the point of impact. In plates badly backed the plate bends slightly back, and very rigid shot occasionally get their points through; but when well backed, the entire plate must be broken in pieces and displaced before a shot gets past it in any sense. In addition to the radial cracks, concentric ones are apt to be developed, sometimes, I think, owing to the tendency of the plate to give back about the point of impact.† Obviously, here tenacity in the shot is called for in a much greater degree than with wrought iron.

* At Spezia in 1882 the steel faces of Brown's and Cammell's plates contained respectively 0·65 and 0·7 per cent., and Schneider's solid steel plate about 0·45 per cent. of carbon.

† Major O'Callaghan, R.A., Shoeburyness, has contributed a paper to the R.A. Institution, containing a most interesting investigation as to the behaviour of steel in

3. *Solid steel*, as made by Schneider and used in many foreign ships, though rather less hard than the steel face of compound plates, is as a mass more rigid. It admits the point of the shot at first with rather less resistance, but it does not yield at the point of impact even when badly backed, and is, therefore, less dependent on backing than compound armour. As the shot enters, it wedges and heaps up the metal round it, the plate coming forward and swelling at the point of impact and yielding by radiating cracks. I have never known of a concentric crack being made in steel armour, nor of the point of the shot getting through until the plate was stripped off. Any cracks made are, I think, much more certain to extend through the metal than in the case of compound plates where face-cracks may be formed, leaving the iron foundation-plate intact.

4. *Chilled iron* made by Grüson, and used almost universally in foreign coast-armoured defences, is very rigid indeed. The shot never, I believe, gets its point even a single inch into the metal. The shield transmits the shock through its mass and must be broken up bodily. Chilled iron is used in large masses, and is best suited to resist single blows, especially in an oblique direction. Under the direct blows of heavy shot of high tenacity chilled iron breaks up. Cracks radiating from the point of impact are formed, and the whole shield breaks across. The primary requirement in the shot appears to be tenacity, to enable it to deliver its work on the point of impact before it breaks up, which it does, leaving little or no metal lodged in the shield.

The first experiments to notice are two carried out by Krupp at Meppen, in March 1882, at targets shown in horizontal section in sketch. They were examples of remarkably successful perforation of wrought iron by steel projectiles. In one case, fig. 1, a 5·9 inch projectile striking directly, passed easily through two

steel-faced plates round the point of impact, with his own explanation and that of Colonel Inglis of the phenomena exhibited. The original paper, No. 2, vol. xii., 1882, should be read by any one who is interested in the matter. Briefly, it may be said that the steel is driven outwards in directions normal to the head of the shot, setting up and buckling as it goes, while the wrought iron yields beneath it, the effect being to produce the separation of the frustrum of a cone of steel from off the face of the target of irregular curved form, with crater-like depressions. It appeared to me that at Spezia the comparatively soft Gregorini shot-points were moulded into a form originated by this action.

7-inch iron plates with 10 inches of wood between, and in the other, fig. 2, striking obliquely at 55° a similar projectile perforated 7·9 inches of iron with 9·84 inches of wood and 0·98 inches of iron skin. In the first experiment, which was repeated, both projectiles passed uninjured up the range. In the second, which was also repeated, both the projectiles broke up. May I call your attention to the local character of the injury effected on the wrought iron, and the completeness of the perforation, especially when the shot strikes directly?

Next come the Spezia trials of November 1882, where steel-faced plates 19 inches thick, supplied by Cammell & Brown, competed with 19-inch solid steel supplied by Schneider. Each plate first received a blow from a chilled Gregorini iron projectile weighing 2000 lbs., fired from a 100-ton gun with sufficient velocity to perforate a wrought iron plate of 19 inches, that is, about 1225 feet per second; secondly, a blow from a similar projectile was delivered on each plate, with a velocity of about 1560 feet, capable of perforating about 25 inches of wrought iron. The figs. Nos. 3 to 12* show the plates after each successive blow. The steel-faced plates became wholly or nearly detached, and fell from the backing on the second blow. The steel remained up, and received two more blows from steel projectiles.

At the same time was commenced a very similar trial at Ochta, near St. Petersburg, where 12-inch Cammel steel-faced and Schneider steel plates were attacked by an 11-inch gun firing chilled iron projectiles with the necessary velocity to perforate 16·3 inches of iron in the first round, and subsequently the necessary velocity to perforate about 12 inches. The diagrams, figs. 13 and 14, show the plates with the effect of the shot on them.

It may be seen that at Spezia the French steel plate stood best, but at Ochta the advantage was still more decidely in favour of the compound plate. Schneider's Spezia plate was tempered, and was held up by twenty bolts, while Cammel & Brown's had only six bolts each. These makers object to the tempering of the steel, urging that their plates were samples of their supply to the *Italia*, for which plates could not be tempered, because the plates are curved. This placed the steel-faced plates at a disadvantage, and the Italian officers consider that the yielding character of the backing told against the steel-faced plates,

* Made on the ground for the "Engineer" by the author.

which would be much more rigidly supported on the ship's side. The fall of the fragments makes the difference between the English and French plates appear greater than it was. There the tendency of the steel-faced plates was to give backwards, and the steel to swell at the point of impact. In the steel-faced plates the fracture may be seen to be concentric as well as radial. The effect of three blows on the steel, and of four on the steel-faced at Ochta, is shown in the diagrams. The steel and steel-faced plates show the character of fracture ascribed to them above.

On August 22, 1883, was commenced a remarkable experiment at Shoeburyness on the resisting power of plates of iron, and steel-faced plates fastened on granite. The iron consisted of two 8-inch plates with 5 inches of wood between, and the steel-faced plate was 12 inches thick. The 80-ton gun was fired at these with a projectile of chilled iron weighing 1700 lbs., with a velocity of nearly 1600 feet, capable of perforating 24 inches of wrought iron. The shot cut a clean hole through the iron, breaking up but penetrating nearly 10 feet into the granite, fig. 15. Against the steel-faced (Cammell's) plate it broke up, the head lodging in the plate, as shown in figs. 16, 17, and 18, cracking and bending, but not breaking or detaching the plate. This last result is an extraordinary one, the plate when thus well supported having borne a blow capable of perforating 24 inches of iron, and containing about 30,000 foot tons energy, showing what steel-faced iron is capable of enduring under these conditions. It may be noticed that there is hardly a trace of concentric cracking here. In the case of the wrought iron may be seen the usual clean perforation.

Three other experiments on perforation deserve notice. Captain Palliser, with a shot whose calculated perforation is about 7·7 inches, completely perforated a wrought iron plate 8·73 inches thick on April 5, 1883, with a special pointed steel-jacketed shot of reduced diameter; and, what perhaps deserves more notice, on June 6, 1882, he *perforated completely a 4-inch steel-faced* plate with a 13-pounder shot of his special pattern, with a striking velocity of 1550 feet, and a calculated perforation of 4·6 inches of wrought iron. He also *perforated* a 6-inch *steel-faced* plate with an 80-pounder shot.

In August last, Sir Joseph Whitworth, with a 9-inch gun, 29 calibres long, drove a forged steel shell weighing 403 lbs. through an

18-inch wrought iron plate, with a striking velocity of about 1900 feet. The projectile had a good deal of work left in it, smashing up a very heavy cast iron supporting plate, and passing through an oak backing and steel skin, and many feet of wet sand. The projectile is a most remarkable one. I am happy to be able to show it to you, through the kindness of Sir J. Whitworth. In all these last experiments the work is strictly local, especially deserving notice on this account in the case of the steel-faced 4-inch plate.

Finally, I would mention an experiment of a totally different character, namely, one conducted at Buckau, Magdeburg, by Grüson on October 22, 1883, when a chilled iron shield with a maximum thickness of 43 inches, weighing 47½ tons, was attacked by a 12-inch Krupp gun (30·5 c.m.), firing a steel projectile weighing about 980 lbs., with a striking velocity of about 1460 feet, and having an energy, therefore, of about 14,500 foot tons. After three rounds the shield was cracked or broken across in more than one direction, and a fourth shot began the actual displacement of the fragments. There was nothing here of the nature of penetration, the surface only at the points of impact being chipped off. Considering the destruction as effected by the shock on the mass of metal, it may be in a sense measured by the energy per ton of shield; this amounts to 916 foot tons in the whole three blows.

The steel-faced plate on granite at Shoeburyness weighed about 10½ tons probably. It received a blow of a shot with 30,000 foot tons energy, or about 2857 tons per ton of metal. We must not, of course, compare this with Grüson's shield, because being backed with granite the plate only represents a portion of the shield, but it is easy to see that it held together under a vast blow. The work on the Grüson shield was delivered in three blows and distributed. The Grüson shield was broken up; our Shoebury one was not; but there would have been a better chance of completely dividing it if a steel shot had been employed. This would have held better together, and perhaps set up, following the opening parts of the plate, instead of a rigid chilled iron shot shivering directly it began to lose its form. My object to-day, however, is not so much to make a comparison of the total resisting power of the different classes of armour as to indicate the shape in which the work has to be done, and the consequent mechanical bearings of the question.

I think it will be clear to all present that, in the case of wrought iron, we have simply to deal with perforation. In the first days of the Plate Committee, Sir William Fairbairn suggested an equation for the calculation of this work, which, with slight modification, answers very well to the present day. Indeed, it happens to require less empirical correction with the present guns firing long projectiles at high velocities than those employed in early days. This equation is simply—

$$\frac{Wv^2}{2g} = \pi D t^2 k$$

where W equals the weight of shot, D the diameter of shot or hole made, v the striking velocity of the force of gravity, t the thickness of plate perforated, and k a constant to be determined practically. The equation consists in putting the total energy or stored-up work in the shot at the moment of impact equal to the work performed on the plate. The left-hand side is absolutely true, and the right-hand side can be shown to be correct in a measure; the only term that is empirical to the full extent is t^2; but under the most important conditions it happens to be most nearly correct. The formula does not apply to cases of partial penetration; but as partial penetration is useless, it really gives us all we need for wrought iron.

To pass on to other cases, we may now and then, in compound plates, get actual perforation, or we may get an instance when a steel shot sets up and drives a disc out of a compound plate, which action may partake of the nature of perforation. With most compound plates and all solid steel, however, you will observe that the plates are destroyed by fracture, the shot's point penetrating to an insignificant depth. Here, then, we have only fracture caused by a blow delivered by an ogival-pointed wedge. It differs wholly from perforation; for while in both cases the stored-up work or energy is the motive power, in perforation the thickness perforated depends inversely on the size of the hole or diameter of shot; whereas in destruction by fracture the point only of the shot enters the plate, and its diameter can scarcely enter into the question. We may suppose, when all other conditions are the same, that fracture effected on any given plate may be simply proportional to the stored-up work; but this fact is of little use to us, for other con-

ditions will very seldom be the same as that of some known example. We want to be able to calculate for varying dimensions of plate and velocity and weight of shot, and this at present we cannot do.

The general method of matching a shot against a steel-faced or steel plate is to give the shot sufficient striking energy to perforate wrought iron of the same thickness, or else of 20 per cent. more thickness than the compound or steel plate attacked.

The table herewith shows this to have been the method followed at Shoeburyness, at Spezia, and at St. Petersburg. In each case, the power of the shot to injure armour, which you observe was destroyed by *fracture*, was calculated on the basis of *perforation*. It is easy to show that this is a totally false principle. Surely armour ought to be divided into two distinct classes, which we may term "*soft*" and "*hard*," the former signifying armour which is perforated, and the latter, armour which refuses to yield in this way, and must be broken up. I have tried to illustrate the difference by means of a "dropping apparatus" or "pile-driving machine," which the Director of Artillery kindly allowed me to have made in the Arsenal. There is a weight into which punches, representing ogival shot of different sizes, can be fixed. It would be wrong to assume that results obtained by such insignificant forces necessarily represent what occurs in firing at armour; but we may illustrate principles thus, if it turns out, as it does, that the results here obtained are nearly in accordance with the formula which is proved to be correct, and is in use for problems in armour-piercing. Indeed, I got the machine made, feeling confident that this would be the case. Wrought iron is here represented by millboard slabs, and hard armour by hard brick. The perforations in the millboard slabs are so like those made in iron plates that a photograph of one might almost be mistaken for the other. The hard brick so far resembles hard armour that the point of the shot-punch enters a very short distance before fracture occurs. To test Fairbairn's equation, $\frac{Wv^2}{2g} = \Pi Dt^2k$; as the velocity is here due to a fall, we may substitute WH (weight into height) for the stored-up work $\frac{Wv^2}{2g}$ and write $WH = \Pi\, Dt^2R$.

Nothing can well be more simple than this, and you can

see that it is fairly carried out, as you can see the height from which the weight drops. It is easy to take one pair of terms and test how one affects the other, leaving all the other terms constant. Here, to bring out my point, I change the diameter and try its effect on H, the height of fall. If I double the D, obviously if the W is kept unaltered I must double the H. Multiply the D by 4, and I must multiply the H by 4. Thus the quarter-inch shot punch at 10 inches fall should perforate the same slab as the half-inch punch with 20 inches fall, and the inch punch with 40 inches fall. At the lowest heights there is some irregularity, but still this is approximately true; the inch punch you observe perforates this slab at about 60 inches and the quarter-inch at about 17 inches fall, because the latter only requires to make a small hole compared with the former. Observe, then, as to the *thickness perforated, the quarter-inch punch at* 60 *inches is absolutely equal to the inch at* 17 *inches.* So much for *perforation;* now for *smashing hard armour.* The quarter-inch punch breaks the brick slab at 9 inches fall. Now, *no one here can suppose that the inch punch with the same weight behind it requires four times the fall.* You see it is about equal *to it with an equal fall. For perforation, then, the energies required are in the proportion of nearly* 4 *to* 1; *for smashing they are equal.* Does not this show what a totally wrong principle is followed at Shoeburyness, at St. Petersburg, and at Spezia, when the shot is matched against hard armour on the data for perforation? I do not mean that results which are grossly wrong are obtained. I have taken extreme conditions to bring out the error palpably, but this error certainly exists in a degree.* It is much easier, however, to find fault than to suggest a remedy. How can hard armour be dealt with? I have been in the habit, when writing in the *Engineer*, of trying to measure the shock against hard armour by the energy per ton of shield, and only learned recently that Grüson employs the same measure. You will see this applied on the table herewith. Nevertheless, while it is of some use as a check on the perforation figure, it is itself just as wrong in theory. It is quite clear that there must be

* At Copenhagen, in March 1883, a 9-inch old type Woolwich gun and a $5\frac{3}{4}$-inch Krupp were fired together. Their powers of perforation were as 118 and 123, while their total energies were 16,403 and 5760.

some limit as to the distance of the mass we thus deal with from the point of impact. If I strike a long narrow plate near one end, surely it will snap across. The length is immaterial here, and I shall get nearly the same results with two plates, one double the length and weight of the other, and therefore receiving only half the shock per ton. We must not, then, blindly take the whole weight of each plate as the basis of calculation.

The results of fracture constitute so difficult a problem that it has been said that it has nothing to say to mathematical calculation. This, however, you will, I think, not concede. Surely the line of least resistance must be subject to mechanical laws, however hard to discover. Even steel itself, though we may be tempted to think so, is not really capricious, but is bound to follow certain laws. In this question we have no doubt difficult elements. As to dimensions, we have probably primarily to consider the minimum cross measurement as one line of probable fracture, but you will see that from various causes the plate does not always so yield; bolt-holes and other elements may have their influence. Still, while not a guide as to actual direction, the minimum cross measurement may help as to amount of resistance. On the other hand, an increase in the maximum direction or length of a plate is held rather to facilitate cross fracture, just as a long stick is more easily broken than a short one. The actual work of cracking is difficult to investigate. Clearly the first portion of a crack represents much more work than the completion of it, consequently an increase in width of plate would most probably not give a plate a proportional increase in resisting power.

Such a question as this could only be investigated by a very extended series of experiments. I would, however, venture to suggest that much might be done on a very small scale. I understand Mr. Whinfield to say that Sir Joseph Whitworth has found that experiments with bullets represent generally the conditions of similar ones with ordnance. I should think, then, that much might be learned by firing steel bullets against a series of discs of steel and chilled iron, always keeping all conditions uniform, except those whose relation is the object of investigation; comparisons being made as far as possible with such results of experiments with ordnance as we possess.

Be this as it may, is it not obvious that at the present

moment all nations are in want of experiments made with a view to determine the conditions of fracture of hard armour under impact?

In England, we need trials against the hardest classes of armour, that is, solid steel and chilled iron, otherwise our success in perforating iron, and even steel-faced armour, may tend to develop hardness in our shot at the expense of the tenacity that is needed for the hardest classes of foreign armour.* These two classes, solid steel and chilled iron, we ought to have specially in view, because many of the ships which most concern us carry steel, namely, the *Admiral Duperré* and most French ships, as well as the *Duilio* and *Dandolo*, while nearly all foreign coast forts have chilled iron armour.

Chilled iron had been adopted for inland forts as well as coast defences in France, owing to its power to resist chilled shot; but in 1882 steel projectiles were tried against it, and produced such effect that chilled iron was then condemned for inland works, which, it may be observed, are liable to be exposed to more prolonged and systematic fire than coast forts. Should we unfortunately retain our chilled shot after foreign powers adopt steel, the above verdict in France would imply that chilled iron forts are good enough to resist English shot, but not those of other nations.

At Meppen, in 1879, chilled shot failed against a chilled iron shield, and had to be replaced by steel projectiles. If it be urged that the attack of armoured coast forts is an exceptional and un-

* The perforation of steel-faced iron by Palliser's shot which have a steel jacket, moving forward on impact, tempts me to show you a curious example of effects or impact. About twenty-five years ago much attention was attracted at Cambridge b the behaviour of solitaire balls striking together in a groove. This is put in rather more systematic form here in this horseshoe-grooved board. I will drop first one an then larger numbers of balls against the row lying in the groove, always employing blow with the same amount of stored-up work. You will see the variation in the shape i which the work is done. One ball dropped causes one ball to be detached at the oppo site end of the column, two balls detach two, three detach three, and four detach fou I once thought that this was due to the tendency of the work done to retain the sam proportion of weight and velocity as in the blow delivered. This is not so. I drop a iron ball the weight of three glass ones. Observe, three balls do not detach themselve but one only. It almost seemed as if the thing could count; but perhaps you see th cause. It is due to the fact that two, three, or four balls do not strike quite simu taneously, but successively. But I have here two balls, which when I drop will onl detach one, because they are rivetted together. We have then the curious fact th two loose balls detach twice the quantity of material that is detached by two fixe together. Of course we are here dealing with resistance of *inertia*, not resistance *cohesion*. I cannot get any sensible advantage in attaching loose weight to my falli punches, but I have tried the matter very imperfectly.

desirable operation, it must surely be admitted that the weakness here brought out must be exhibited in a measure against other hard structures, and is surely a matter to investigate.

Last year a commission was sent over from America to investigate the condition of iron and steel in Europe. It is said that the report speaks unfavourably of English steel. This is to be understood if it refers to our steel projectiles, which seem specially to need encouragement at the present time.

DISCUSSION.

Captain M'Kinlay said, with regard to the remark that Captain Browne had made, contrasting the kind of armour now used, either made of steel or of steel and wrought iron joined together, he thought he had brought out in a very marked and clear manner the different behaviour of that and of wrought iron alone when struck by a projectile. With the old system of wrought iron it was very easy indeed to tell beforehand what might be effected by a given projectile striking with a given velocity; but it appeared, from the experiments mentioned, and from many others, that with the modern kind of armour now coming into use, not only in this country but in foreign nations, the estimation of probable results beforehand was by no means an easy matter. He mentioned the plate at Shoeburyness which had stood so well—a small steel-faced plate, the resisting power of which was very good indeed; and from the remarks which Captain Browne made as to the manner in which compound armour gave way and the absence of concentric cracks, it would appear that that plate had been only slightly deformed, that it had been kept in its place by the rigid backing behind it. Contrasting with them the behaviour of the compound plates at Spezia, where they broke up, being provided only with soft backing, it would then appear that with the new gun and target, where the target itself was able to give way considerably, such a plate would break up. On the other hand, where the backing was firm and rigid, and the whole plate itself could not be bent out of shape, the resisting power appeared to be very greatly increased. It would be seen, then, that no

estimation of the probable resisting power of any new plate could be well arrived at without a very careful consideration of the backing, whether it was made of granite, which might be used in land fortification, or was composed of the ribs of ships. Many of these experimental targets were put up at various places, but the backing or the frame holding them was not always nearly so rigid as that which would contain it on an actual fortification or a ship to which it really might be applied. The employment of this new kind of armour suggested an advantage which coast forts might have over ships, for the reason that it was easy to give a rigid back to a fort where weight was of little account, and was perhaps not quite so easy to do so in the case of a ship, so that if the plate was struck at some point between the ribs there would not be anything like so good a support as if it had an even surface of granite behind it. Captain Browne said that the heavier the plate, the more able was it to resist the blow. That also seemed to be a point worthy of consideration. On the other hand, with wrought iron it apparently did not matter so much what the size of the plate was—the chief point to depend upon was its thickness. It appeared that a large plate of steel had better resisting powers than a smaller one, because it was able to distribute the blow throughout the whole mass, and apparently the whole plate could take up, more or less, the whole strain. A point of interest mentioned the other day by Mr. Anderson at the United Service Institution, after a paper by Colonel Moncrieff, was this, that with regard to the new kind of armour, such as was placed on the turret of the "Inflexible," which was covered with compound armour, a few years ago an English experiment was made by firing at a turret. The turret had two severe blows, just enough to penetrate it—the object of the experiment being to determine whether the turret could afterwards be revolved, or whether any very decided local damage had been inflicted. That turret revolved freely afterwards. Again, in the case of the *Huascar*, in the war between Chili and Peru, the turret was penetrated by a 9-inch projectile several times, and there again it did not jam, but could be revolved afterwards. It was said the other day that this had not been fully proved to be the case with compound armour. In compound armour the whole effect of the blow was taken by the whole mass

or approximately so, and it was a question whether turrets made of that new kind of armour would not jam after they were hit. That was a point which needed full consideration. With regard to armour-plates, it had often struck him that they had only two manufacturers in England, both being in Sheffield. He had heard that another firm contemplated going into this business, and it would seem to be an advantage, looked at from an international point of view, that other makers should take it up, so that, in case of emergency, they might have several firms to make a large supply of armour if required. At the present time it was contemplated—or, at least, an agitation had been commenced in that direction—to increase the coast defences, and it seemed, therefore, that this subject might be well discussed at a time when there was a probability of a considerable increase being made to those defences.

Mr. J. Riley said he had not had the pleasure of hearing the whole of the paper, but with regard to projectiles, it had often been a cause of wonder to him that more had not been done by the Government with regard to steel projectiles. He had the privilege, some years ago, of sending for trial half-a-dozen shot and shell made of steel. As they were aware, the Terre-Noire works in France made shot and shell very largely, and why those shot and shell should be so much more highly prized abroad than shot similarly made in this country for the same purpose, he really could not understand. He was sorry he could say no more about the paper, but that point appeared to be worthy of mention.

Mr. Davey said it might seem almost an impertinence in him to stand up to say anything upon that paper, as he must confess that he had practically no acquaintance with the subject, but having some knowledge of mechanics, the experiments which Captain Browne had performed suggested an idea to him which he might be excused for putting before the meeting. It occurred to him—he did not know whether the opinion had been suggested before—that if they could destroy some of the energy of the shot before it was brought on to the actual armour-plate which was to form the ultimate protection, it would be a point of great

importance. Mr. Browne, in describing the machine, told them that he had put loose weights on in order to see what the effect would be. Now, supposing the weight to be divided into two equal parts, and a very light spring put between the two, if the two weights were elevated to any given height and then dropped on to a resisting material, the blow struck on that brick, or whatever it might be, would only be the force due to the fall of one weight. The one weight would expend its energy on the material first, and the other would a moment afterwards, so that the force which the energy spent on the material would only be half of the total weight. It occurred to him that if one armour-plate was put in front of the other, the shot, after passing through the first plate, would have so much of its energy spent that it would require a less resisting material behind it. He did not know whether the suggestion was of any value.

Mr. Scattergood said he did not understand the question which had been discussed so ably by Captain Browne, neither did he suppose the manufacturers of iron and steel very well understood the equation given in it, but he took it that all the members of the Institute could clearly understand the last clause in the paper. It concerned every member very intimately, and if Captain Browne had said nothing more than was contained in the last five lines of his paper, he had shown that it was their duty to do the best they could, at any rate, to retrieve what they appeared to have lost—their good name. Captain Browne said, "Last year a Commission was sent over from America to investigate the condition of iron and steel in Europe. It is said that the report speaks unfavourably of English steel." He supposed the object of bringing the paper before them was to induce, as far as possible, the manufacturers of steel to make better steel than they had hitherto done, in order that they might maintain the position they once held. Perhaps that would go a little distance towards explaining what had been said—that the Government was not willing to make trials of projectiles.

The President said he did not know whether there would be any further discussion on this paper, but he did not think they ought to allow it to proceed without his remarking that Captain

Browne distinctly stated that the steel was found not to be suitable for a given purpose. No fault was found with the steel as steel, and it was for those gentlemen who conducted experiments like those of which Captain Browne had spoken to tell the steel manufacturers of that country what were the precise qualities of steel required for their purposes. He had no doubt that, whenever that was done, English manufacturers would be able to produce steel of a given degree of hardness to satisfy the requirements of artillerists. He thought it was desirable not to allow a false impression to go forth for one moment without making that observation upon it.

Mr. T. NORDENFELDT said he believed the reason why English manufacturers had had so little chance of showing what could be done in projectiles, as well as in other produce of a similar nature, was that they had so little opportunity of trying what they made. It was only a matter of money. They had in England a school of gunnery, with highly intelligent and active officers. The captain there had two assistants. But the marine artillery in France, independently of the land artillery, kept a staff of sixteen officers who did nothing else but experiment with the manufactures of the steelmakers of that country. He repeated, it was a matter of money. The Treasury did not like to ask for the money, and the intelligent officers—really very clever and experienced men—who had charge of the Government factories dared not ask for money, or, if they did, they might be snubbed. He believed that the experts who had charge of those matters in this country not only entirely followed Captain Browne, but went almost farther than he did in admitting the value of the steel, and in admitting that in this country steel projectiles had been made by the manufacturers which really and actually had done quite as much, if not more, than the French steel projectiles. It was about three years ago that those projectiles were fired, and since then the officers in charge of the departments did not feel justified in asking manufacturers to make further experiments in steel projectiles, because they had no money to buy them, and because they dared not ask the Treasury to provide the money to try them if they did buy them. In comparison with other countries it was remarkable what good results were

obtained in England with so small an expenditure for experimental firing.

The PRESIDENT said it was now his pleasing duty to record a vote of thanks to Captain Browne for his extremely interesting paper, which opened up many subjects well worthy of the consideration not only of his own profession, but also of the iron and steel manufacturers of England. He was sure they were all very much indebted to him—not the iron and steel manufacturers only, but the nation as well was indebted to him, for having called their attention to this very serious point of the nature of the projectiles which should be prepared for firing against armour of different descriptions. It would be very desirable that they should be informed what should be the specific nature of the steel which the Government would in the first instance be willing to test for the purpose to which the author had referred. There was nothing better understood than the production of steel, of any given degree of tenacity and hardness. All that the English manufacturers required was to be told what were to be the qualities which were best adapted for the purpose intended, viz., the breaking-up—because he supposed penetration would be out of the question—of the hard armour-plates which were now so generally adopted both in this country and abroad. He proposed that they should give their best thanks to Captain Orde Browne before he replied to the observations that had been made.

The meeting accorded a vote of thanks by acclamation.

Captain ORDE-BROWNE, replying to what Captain M'Kinlay had said as to the introduction of hard armour, stated that he hoped he had made it clear that it was so intolerable to have a hole made in a shield, and to get a shell carrying fire through it into the interior, that he looked upon it as a certainty that armour would always be made hard enough to stop that. The introduction of "*hard*" armour was having a greater effect upon shot than people were quite aware of. Economy, which they heard spoken of just now, was such a very strong power that it always compelled them to try their own shot against their own armour, and he had told the authorities—and there was no reason why he

should not repeat it—that they ought not to be contented with trying wrought iron and steel-faced armour. The steel-faced was the softest armour that existed, with the exception of wrought iron, and yet it happened to be our hardest armour in this country. Other countries used steel, which was harder, and chilled steel, which was harder still. There was no doubt that those extremely hard kinds of armour called for a different class of projectile to that which we had been in the habit of using in this country. Chilled shot, which did very well for wrought iron, failed against chilled armour. Krupp carried out an experiment of a peculiar character in 1879. He wanted to show that a wrought iron was better than a chilled iron shield. Grüson manufactured chilled iron, and he was a rival of Krupp, and Krupp wanted to show that his rival's shield was a bad one. He accordingly made a specimen of his rival's shield and of his own, and said that he was going to attack them both by chilled projectiles. But after firing two or three rounds he found that his rival's shield stood so much better than he expected, that he took to steel instead, and then in time he broke it up. Captain Orde-Browne did not notice the consequence of that at the moment, but looking back upon it, it was easy to see what it meant. A chilled shot going through soft armour would break up, but the broken shot would go on and get through, and its point remained perfectly sharp. A softer shot would set up more in a way that seemed to be greatly against penetration, but was better for very hard armour, because if both shot were abruptly resisted before the shot got the support which they did during penetration, the hard shot would smash to pieces, producing but little effect, and the softer shot would produce more effect, although it spread open and eventually broke up. A few experiments had been made, which had shown that they were rather running on wrong lines in this country, because they kept on using armour which did not bring out the full value and tenacity of the shot. They had very few experiments to refer to, because they had never fired at chilled iron or steel in this country. When he said "never," he had seen one steel target fired at, belonging to Sir Joseph Whitworth, but that was a small experiment. Chilled iron was once fired at over twelve years ago, but it was then in a very embryo condition. He thought it was

very detrimental to this country that they did not try their shot against the very hard systems of armour used abroad. There was one fact to which attention had been called by Captain M'Kinlay, as to the bearing of softness of armour on the question of turrets. Soft armour yielded locally, and the experiments made against the *Glatton* turret many years ago showed that, however much they could perforate a wrought iron turret, they did not dislocate it. The turret worked round just as well as before being struck. It might have a hole made in it, but it would turn round, and they knew that as guns had now got rather smaller bores, weight for weight, and the shot had higher velocities, they would penetrate still better. *Penetration*, however, would not dislocate or bend a structure. The power to bend depended on the resistance in the act of going through, and therefore it looked as if the wrought iron turret would not be affected at all by the fact that they had shot of greater powers of *perforation*, because the shot fired at the *Glatton* turret very nearly perforated it—that is, it nearly performed all the possible dislocating work that could be done for the size of the hole it made, and still the turret worked very well after the blow. But now, if they substituted hard armour for soft, the work was *distributed through the whole mass*, and it was more likely to move the mass. He had seen a steel-faced target at Shoeburyness, in which the whole plate was driven back several inches; it was not well backed, but they never could see an effect like that on wrought iron. That was a serious thing for a turret, because the shot might often have *sufficient work in it* to lift the entire turret up above the topmast, if it could be put in a suitable shape to effect this end; and therefore the reason that it did not dislocate the turret was because the action of the blow was *local* and *rapid*. Once put armour on of such a nature that the blow was more likely to be distributed, and the value of the *Glatton* experiment was in a measure damaged. The "Inflexible" turret, and those of impregnable ships, had steel-faced armour, and as they went on to harder armour there was no doubt there might come a time when it might be necessary to try further experiments, such as again firing at an armour-plated ship. At all events, it would be necessary to watch how far plates recoiled bodily when they were made of hard armour.

With regard to double plates, the question was too large a one

to discuss there. There were some very remarkable effects produced by double plates. He might just mention two things which would show what very unexpected effects were produced. One was, that if they had two plates with a space in between them, and they fired a chilled shot at them, the chilled shot would go through a comparatively insignificant front plate, and then, on striking the back plate, it would fly into powder or dust. This property in the plates, however, could not be utilised, firstly, because foreign nations did not use chilled shot, and, in the next place, because they might fire a shell which would get through far enough to blow the front plate off. The second result he would refer to was, that if they had a steel plate which was capable of keeping out a certain shot, and if they put a thin wrought iron plate in front of that steel plate, the shot that was before kept out by the steel alone might now go through iron, steel, and all; and for this reason, that it was not resisted when its point only was touched. If a plate's surface resisted the shot when its point only was touching, an outward thrust was developed which smashed the shot to pieces; but once allow the shot to get its head in, it then became supported all round and would go through. Those two illustrations would show how many things there were to be considered. He would now pass on to the very much more important question of the manufacture of steel shot. And first with regard to the paragraph in his paper, which had been quoted, in which he had stated that the Americans spoke unfavourably of English steel. He hoped he was not responsible for everything that all Americans said. The report was not out yet, but it had been darkly hinted to him that it was stated in the report that English steel was in a bad state. He could only attribute that to the fact that we had not made steel shot on a large scale. And why had we not? Because the Government had not sufficiently encouraged it. He knew no other reason. He did not think that the Government fully appreciated the position of the question. They had some very excellent steel shot. There was a steel Whitworth shot at that moment in the lobby outside the theatre that had been through 18 inches of wrought iron, which, however, did not affect it much. It then came across a cast-iron girder, and that had turned its point a little; but it was a magnificent projectile, and they

must not at all suppose that excellent projectiles were not to be made in England. Other firms had occasionally turned out excellent projectiles. A magnificent one from Cammell's was fired on one occasion, but they were chiefly made by Sir Joseph Whitworth, and for this reason it was an extremely expensive thing to perfect the manufacture of steel projectiles. Steel projectiles themselves were rather expensive, but they had to prove them against targets, and the targets cost large sums of money; and the evil was that if any gentleman were to make a steel projectile, and sent it to Shoeburyness to be tested, it would be regarded as his champion projectile. On the other hand, he would only be able to try it privately—trying so far as he had money to spend at the rate of perhaps £4000 or £5000 for each shield—and he could not try more than two or three at each plate. If a shot on a Government trial turned out badly, the maker's reputation was staked upon it. He had had an interview with the Ordnance Committee once, and had tried to put this to them. Many projectiles were expended every year in proving the plates of ships. They cut a piece off each plate, and proved it with service chilled iron projectiles. They did not want to learn anything about the projectile, but they wished to know if the plate was up to a certain standard, in order that it might be passed for the service. In that way a number of chilled projectiles were fired away, and his object was to get an opportunity of firing experimental steel ones instead. He tried to suggest to the Committee that as soon as ever they could make up their minds that the plate was going to pass for the service, they might let the steelmakers have their steel projectiles tried against that plate. He put that to the Committee, and the answer he received was that the steelmakers would not send steel shot to be tried at Shoeburyness at Government expense, and that as they would not send them to Shoeburyness, it could not be supposed that they would send their projectiles to be tried at Portsmouth, as regarded the shot, at their own expense. He endeavoured to point out this great difference, that makers would submit steel shot as *test* shot, but that they would not put forward a *champion* shot. A man would readily send a steel shot to be tried, and see what it would do, as long as his reputation was not supposed to stand upon it. But so long as steelmakers could only send shot that were going

to be treated as champion shot, or else have to try them at the rate of £5000 a target, he did not see how they could develop the manufacture of steel shot, except, perhaps, in the case of Sir Joseph Whitworth, or some one or two others that he could name. That was the position in which they stood at this moment. He believed that the manufacture of steel shot in this country wanted developing very much indeed. He would also call attention to the circumstance that the French a year and a half or two years ago, positively adopted cast iron chilled armour throughout the country, and found it good as long as they fired chilled shot. When once they fired steel shot they condemned it, except for coast use. Now, at that moment, all the English ships carried chilled iron shot, and not steel. The chilled iron turrets were good enough to resist chilled iron shot, but not for steel shot, and any foreign nation that adopted steel shot would be in a better position than our own. That appeared to him to be a serious thing. Anything that could be done to prove the necessity for the manufacture of steel projectiles in this country would, he believed, be found to be benefiting England, and that was one of his reasons for bringing forward that paper.

The meeting was adjourned until the following day.

FRIDAY, MAY 2ND.

The Institute resumed its sittings this forenoon—BERNHARD SAMUELSON, Esq., M.P., F.R.S. (President), again occupying the chair.

The first paper read was :—

ON RECENT IMPROVEMENTS IN IRON AND STEEL SHIPBUILDING.

By Mr. WILLIAM JOHN, Barrow-in-Furness.

When I received an invitation from the Council of this Institute to read a paper upon recent improvements in iron and steel shipbuilding, I felt it to be an exceedingly high honour, and one which I could not refuse to accept. At the same time there was a drawback in connection with it—viz., that the great interest which has been shown, during the last five or six years, as to the relative merits of iron and steel for shipbuilding or marine purposes, has materially abated, for the principal questions which agitated the minds of the members of this and kindred institutions have been to a great extent set at rest. This, however, I thought, was as well known to your Council as to myself, and, therefore, I assumed that they did not expect anything novel or striking, but a general *resumé* of the subject and its present aspects from a shipbuilder's point of view.

The question, however, so far as the material used in shipbuilding is concerned, is not entirely set at rest, and probably never will be; and I will endeavour, later on in this paper, to indicate the directions in which, I think, we have to look for further improvements.

So far, again, as improvements in the arrangement of the material used for shipbuilding are concerned, there has not been much done of a striking character, but what has been done I will endeavour to lay before you.

The principal improvements in progress at the present moment are connected with marine engine and boilers, and these also I will briefly touch upon, although they do not, perhaps, come strictly within the scope of this paper.

To return to the question of material. You will all remember

the interesting description given us by Sir Henry Bessemer, in the discussion of Mr. Barnaby's paper, in 1879, relative to the first introduction of his steel to shipbuilding more than twenty years ago, when it was first applied to two stern-wheel barges, then to a paddle-steamer and two sailing ships of an aggregate tonnage of 2911 tons in 1864, and afterwards to six large ships of an aggregate of 5342 tons in 1865—this being followed by the discovery, immediately afterwards, that steel, at the price at which it could then be manufactured, could not compete with iron in shipbuilding. From that time up to about 1877 little or nothing was done in steel shipbuilding. The only exception, I believe, to those years—which were blank so far as the mercantile marine is concerned—was its partial use in some of the Government iron-clads for longitudinal girders in the bottom, and stringer-plates where heavy longitudinal strains had to be met. We next come to the period which, although not the beginning, was at least the resuscitation of steel shipbuilding, and a period from which it has been destined to grow steadily until now. Mr. Barnaby's paper, read in 1875 before the Institution of Naval Architects, drew attention to the large extent to which steel was being used in the French Navy, and was to some extent a challenge to the steel-makers of this country to produce mild steel fit for shipbuilding. This challenge was taken up by Mr. Riley, then manager at the Landore Steel Works, in a paper (read before the Institution of Naval Architects in 1876) which showed conclusively that mild steel of the highest quality fit for shipbuilding could be produced in large quantities in this country if the demand sprang up for it. That paper awoke, for the first time, a real interest in the material referred to among the shipbuilders and shipowners of the country, and the Committee at Lloyds' Register of Shipping, influenced by their principal professional officers, were among the first to throw themselves heartily into the matter, and to propagate the movement.

Extensive experiments were made all over the country, with the active aid of nearly all the principal steel-makers, to ascertain how far uniformity was to be insured with a moderate tensile strength and great ductility, not only by the Siemens-Martin process, which was the quality made by Mr. Riley at Landore, but also by the Bessemer process, as employed at numerous other

works; and it was established, almost beyond doubt, that mild steel could be made, by either the one process or the other, of a quality to far surpass iron for shipbuilding purposes, and at a cost which brought it into pretty close competition with the older-established material.

The difficulties, however, were by no means entirely got over, for, as experiment after experiment proceeded, it was found that steel—especially plates of moderate thickness—became more deteriorated by punching than iron, and it took some time to establish the fact that this deterioration could be removed by riming the hole a little larger without having to resort to drilling. Suspicion still clung to the material, owing to reports of individual plates having cracked in a mysterious manner, and this was further intensified by the remarkable failure of the boiler-plates for the Russian yacht *Livadia*, of some steel angle-bars employed at Chatham Dockyard, and, still later, by some material that behaved in an unsatisfactory, and at first mysterious manner, in Mr. Denny's yard. Some of these failures led, as will be remembered, to most animated discussions in this Institute, and notably, in 1879, relative to Mr. Barnaby's paper descriptive of the failures at Chatham.

I need not dwell upon the long controversies that took place between the shipbuilders, the steel-makers, and Lloyds' Committee, concerning the question whether steel employed for shipbuilding should be tested at the makers' works or at the shipbuilders' yards, although it formed by no means an unimportant feature in the case. Suffice it to say, that the decision ultimately arrived at—to test it at the steel-works, instead of at the shipyards—has proved eminently satisfactory, which never could have been the case if the metal had been tested at the builders' yards.

Since those days, however, which were almost purely experimental days, the question has passed into one of extensive practical experience, as will be seen from the following tables, which show the growth of steel shipbuilding from 1878 to the present time. (See next page.)

The first table, marked A, shows for each year the number and tonnage of steel and iron ships, both sailing and steamers, classed in Lloyds' Register; while table B shows similar figures

A.

Statement showing the Number and Tonnage of Steel and Iron Vessels classed by Lloyds' Register of British and Foreign Shipping during the Years 1878 *to* 1883, *both inclusive.*

Year.	Steel.				Iron.				Total.				Percentage.			
	Steam.		Sailing.		Steam.		Sailing.		Steel.		Iron.		Steel.		Iron.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
1878	7	4,470			329	406,196	106	111,496	7	4,470	435	517,692	1·6	·85	98·4	99·15
1879	8	14,300	1	1,700	318	436,339	30	34,630	9	16,000	348	470,969	2·52	3·28	97·48	96·72
1880	21	34,031	2	1,342	324	422,622	31	37,372	23	35,373	355	459,994	6·1	7·14	93·9	92·86
1881	20	39,240	3	3,167	401	622,440	51	74,284	23	42,407	452	696,724	4·8	5·74	95·2	94·26
1882	55	113,364	8	12,477	457	742,244	68	108,831	63	125,841	525	851,075	10·7	12·9	89·3	87·1
1883	94	150,725	15	15,703	576	817,584	68	116,190	109	166,428	644	933,774	14·47	15·12	85·53	84·88

B.

Statement showing the Number and Tonnage of Steel and Iron Vessels built in the United Kingdom and Registered therein during the Years 1879 *to* 1883, *both inclusive.*

Year.	Steel.				Iron.				Total.				Percentage.			
	Steam.		Sailing.		Steam.		Sailing.		Steel.		Iron.		Steel.		Iron.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
1879	22	19,522	1	1,700	337	428,082	33	35,332	23	21,222	370	463,414	5·83	4·38	94·15	95·62
1880	26	36,493	4	1,671	362	447,389	39	40,015	30	38,164	401	487,404	6·96	7·26	93·04	92·74
1881	34	68,366	3	3,167	411	590,503	50	68,650	37	71,533	461	659,153	7·43	9·79	92·57	90·21
1882	65	115,449	8	12,478	446	672,740	83	112,852	73	127,927	529	785,592	12·14	14·0	87·86	86·0
1883	92	141,552	11	14,193	548	742,292	72	114,698	103	155,745	620	856,990	14·24	15·37	85·76	84·63

for the whole of the steel and iron shipping registered in the United Kingdom from the year 1879 down to the present. Unfortunately, neither of these tables shows the actual quantity of shipping, either steel or iron, built in this country, because there would have to be a small percentage, perhaps between ten and twenty, to be added to those classed at Lloyds' on table A for unclassed ships, and there would be a certain proportion, which I am unable to ascertain, to be added to the figures on table B for ships built for foreign owners in this country and not entered upon the British Register. However, the figures in themselves are sufficiently significant of the enormous growth of steel shipbuilding within the last six years, and it will be seen at once, as I have said before, that steel as a material for shipbuilding has passed entirely out of the experimental stage, and must be judged henceforth by the results of its working in the shipyards, and by the results of the performances of the ships already afloat, both as profit-earning machines for their owners, by their general wear and tear, for their safety against strains at sea, and in cases of collision and stranding.

I think no one will deny in the present day, from the more extended view we are able to take of it after the large experience gained, that the sensational cases which I have alluded to above were quite exceptions, arising sometimes from peculiar defects in the material, sometimes from unfair manipulation, and sometimes from a combination of both.

I am speaking now of the cases which have occurred in this country in reference to fractures. I believe that quite recently equally striking cases have occurred on the Continent, which have been fully investigated by Mr. Martell, the chief Surveyor at Lloyds', and I hope he will be able to enlighten us upon them.

We have built at the Barrow Shipbuilding Company's Works, during the last five years, nine steel vessels, varying in size from very small ones up to vessels of 4000 tons, and of an aggregate tonnage of 19,157 tons, with a total quantity of material amounting to 10,750 tons. During the same period we have built 80,000 tons of iron shipping, employing about 46,800 of invoiced iron. From this it will be seen that about 20 per cent. of the tonnage, 99,157 tons, built at Barrow during the five years has

been of steel, and out of the whole of the material so employed we have not had the slightest trouble with either plates or angles, or beams in steel; but it has been far different with iron.

Messrs. Denny Brothers, who were the first among shipbuilders to take up the question of steel vigorously, and who have kept the lead in it, have built, during the same period, nearly 68,000 tons of steel shipping, out of a total of about 96,000 tons, amounting to over 70 per cent. of their total.

Mr. William Denny, as you will remember, gave his views very fully before this Institute in a valuable paper he read here in 1881, and further experience has confirmed him in those views as I know from a communication received from him a few days ago, in which he says, "Steel has become so uniform as to have lost interest, while iron absorbs attention from its deterioration and want of uniformity, and the men complain if they are put to work iron on account of the amount of spoilt work involved." I believe, from what I can learn, that this experience of Messrs. Denny and ourselves in the working of steel in the shipyard is borne out in other yards about the country. I need not lay before you statistics of the results of the tests made on the steel used in our works within the last few years, because they would be merely a repetition of the kind of tables that you have embodied in abundance in your Transactions.

The only point of real interest remaining to me, in connection with the steel we have been using in the last few years, is the effect of punching upon the thicker plates. I mean when we get up to $\frac{3}{4}$ inch and upwards. I have seen plates lose 30 per cent. in punching when they got above $\frac{1}{2}$ inch thickness, but I doubt whether the experiments have been sufficiently extensive to show clearly whether this is universal where the plates are of the finest quality, or whether they are to some extent exceptional experiments. I hope we shall get extensive experiments on this matter. It is one of great importance when we come to the construction of large ships. It is true, riming or drilling can be resorted to, but I think we need some further information yet in reference to these thicker plates. Another point which I should much like to see cleared up by some of the steel-makers present is the real cause of the failures that took place some time ago, when, for instance, material in which the chemical analysis

showed nothing abnormal, and which would bend double when the edges were carefully planed and prepared, broke off like glass when the edges were rough, or when holes were punched in the material. I must confess I have never yet heard a satisfactory explanation of the phenomenon. There is another point which I should like some explanation upon: it is as to the effect of successive heating upon steel; and the point has occurred to my mind from this fact, that where we have a very difficult plate to fit, such as in some cases the oxter plates at the stern, and it cannot be got to the shape in one heating, the plate has to be put in the furnace again and reheated, and although it may have worked exceedingly well in the first heating, it is much more difficult to work it in the second heating, while if it has to get a third heating, the material gets almost entirely spoilt and unworkable. This is a matter which I do not quite see the reason for, and I have therefore mentioned it in the hope of getting an explanation from those who are much more versed in the qualities of steel than I am.

Up to the present I have dwelt almost entirely upon steel, and I have only mentioned iron incidentally; but it must by no means be supposed that the quality of iron is less important to shipbuilders at the present time than the quality of steel. Indeed, when we consider that in spite of the great strides made by steel, there is still between five and six times as much iron used in shipbuilding as there is of steel, its practical importance is seen to be overwhelming, and it is likely to be so for a few years to come. Our own experience at the present time is most unsatisfactory. Over and over again we have vessels kept waiting on the stocks, unable to proceed, because of iron plates being condemned and having to be replaced. In one very large vessel that we built a few years ago, the whole of two strakes of plating right round the ship were condemned, and only within the last two months we have had as many as seven or eight plates in a single sheer-strake condemned, while at the present moment we have twenty plates condemned for a small vessel of 200 feet long, some of them having to be cut off after rivetting. The delay in cases of this sort is most serious, as well as the cost of the labour upon the plates. Of course the manufacturers replace them, but they do not recompense builders for the labour put

upon the plates before the defects are discovered, nor for the delay in the completion of the vessel due to the cause stated.

It is true that, where the case is a glaring one, we find the makers prepared to meet us to some extent upon the labour spent as well as in renewing the plates, but it is not always so. I am sure most builders must feel that it could be a benefit to themselves and to the quality of the iron generally used in shipbuilding, and a great saving of time, if some system could be perfected by which iron could be tested at the makers' works in the same way as steel is done at the present time. During last year, out of 7500 tons of iron used by us, no less than 33 tons were condemned.

Next to the actual qualities of the material, we might perhaps take the commercial side of the question, as between iron and steel. This was first dealt with publicly, I think, in a paper by Mr. Martell, read before the Institution of Naval Architects in 1878. Mr. Martell there showed that a cargo steamer, 316 feet long, by 36 feet beam, by 25 feet 6 inches depth of hold, with a gross register of 2300 tons, and 200 horse-power, could at that time be built in steel, so as to be a more profitable ship than if built in iron. And the same is true in the case of a large sailing ship, 1700 tons gross register. He also showed that a small screw-steamer for the ore trade would be more profitable if built of steel than if built of iron.

The question was next ably treated, in 1881, before this Institute by Mr. William Denny, who showed, by most careful analysis, that for a large 4000-ton steamer, trading between London and Calcutta, steel was at that time the most profitable material employed, and instanced the Peninsular and Oriental Steam Navigation Company, and the British India Company, as proof that his figures were being realised in practice. Mr. Denny then gave a very interesting comparison between a certain size ship in iron, and a ship of similar size in steel which would be required to carry the same dead-weight; and after showing that the steel ship, although dearer, would be the more profitable of the two, he went on to analyse what fall in the price of steel would be required to bring the actual cost of the steel ship and the iron ship to the same. He found it to be 20s. per ton. The difference in the price of steel and the price of iron at that time

was £3, 5s., so that had the difference been £2, 5s. the steel ship could not have been built to carry the same weight at the same price as the iron ship.

At the present time, the difference between steel and iron is as nearly as possible this amount. According to our last quotations, the difference in the overhead price of iron and steel is nearly £2, 4s. per ton, so that we have reached the point which Mr. Denny indicated; and we could at the present time, I believe, build a steel vessel to fulfil all the conditions of an iron vessel, but of somewhat smaller dimensions, for practically the same price, or rather less. In the case of two sister vessels, which we built last year—one of iron and the other of steel—of the following dimensions:—240 ft. × 34 ft. × 16 ft. 6 in. moulded, 1191 gross tonnage—the difference in the carrying capacity in favour of the steel ship was 50 tons upon a total of about 1450, and the difference in the cost of the two vessels was somewhat under £500, so that the cost of difference of dead-weight between these two ships was less than £10 per ton, whereas the actual cost of the remaining dead-weight was about £15 per ton. In this case, the difference between the cost of iron per ton and the cost of steel was £2, 17s. 9d., and if we reduce this to a difference of £2, 4s., as at present, and reduce the steel ship in size so as to carry the same as the iron one, it will be found that the steel ship will be the cheaper of the two. Speaking roughly, the difference between the price of iron and that of steel has fluctuated in the last five years from about £2, 10s. in 1879 to £4, 5s. in 1880, £3 in 1881, £2, 10s. in 1882 to £2, 18s. in 1883, and £2, 4s. now.

These figures, it will be seen, are highest about 1880 and 1881, and the fact is curiously reflected in table A, where there is an apparent check in the progrees of steel shipbuilding, due to the excessive prices charged for steel. You will see that, taking the vessels classed in Lloyds' in 1878, ·85 per cent. were of steel; in 1879, 3·28; in 1880, 7·14; and then, in 1881, it falls back to 5·74, to rise again in 1882 to 12·9, and in 1883 to 15·12. This period of 1881 was evidently one when the price of steel was excessively high; but the steel-works then in existence could not cope with the work, there were great complaints with regard to delivery, and there is no doubt that at that time the demand far exceeded the supply, and led, fortunately for the

progress of steel shipbuilding, to the establishment of a number of new works in Scotland for the manufacture of steel plates and angles. Indeed, so far as I can judge, steel-shipbuilding has continued to progress as fast as the supply of steel at reasonable prices, and within reasonable time, has admitted of its doing so.

I have taken out a few other figures for ships recently built by our Company with a view to show the difference it would have made at different times if vessels had been built of steel instead of iron. In the case of a large passenger steamer of about 6000 tons, contracted for in 1881, the difference of cost would have been £3500 in steel over iron, and this would have admitted of 400 tons greater carrying capacity, which, you will see, is under £9 per ton. The difference at present would be trifling. In the case of two vessels of nearly the same size, carrying capacity, and length, of about 3500 tons gross—one contracted for in 1880, the other in 1882—there is a marked difference. In the first of these vessels, contracted for in November 1880, the difference in cost, if built of iron instead of steel, would have been £4000, and the difference of carrying capacity 240 tons, whereas in the other ship contracted for in 1882, of nearly equal size, where the difference is 260 tons, the difference in cost, if built of iron, would have been only £2000. This arises from the fact that in the one year the difference between iron and steel was £4, 10s., in the other under £3 per ton. I think I have said sufficient to show you that we are just at the present moment in that position when a slight further reduction in the price of steel, or a rise in the price of iron if steel retains its present price, would again give a great impetus to the building of steel ships, which would, of course, continue until it was again checked by the rise in price, or the impossibility of supplying the demand.

I next come to the question of strength; and here, I think, experience will tell in the long run decidedly in favour of steel ships even at the present reduction of scantlings sanctioned by Lloyds'. We have heard of some recent cases of vessels which have been strained at sea, in which the straining has been attributed to their having been built of steel, which, for my part, I should be more inclined to attribute to excessive proportions. It has been said that steel ships vibrate more than iron ships. I can only say that, so far as my experience goes, I have not seen this to

be the case. I know it has not been the case in any of the steel ships we have built, and I can give you the highest testimony in the country, to the effect that in the *Pembroke Castle*, built of steel, you could scarcely tell whether the engines were going full speed or not; and the same remark applies to another little vessel, the *Takapuna*, in which the engine power was probably as great as it is in any other ocean-going ship of her size afloat, although the vibration was imperceptible. Again, as an illustration of the strength of steel vessels, take the case that recently astonished everybody who is connected with shipping of the *Duke of Westminster*, a vessel 400 feet long, built by us, which bumped for a week on stony ground at the back of the Isle of Wight without making a drop of water, which could not possibly have been the case with an iron ship. In fact, the bottom plating of the *Duke of Westminster*, as she appeared in dry dock, was corrugated between the frames for more than half the length of the vessel, and yet not a single plate was cracked, nor a rivet started. Another case of an equally striking character is that of the British India Company's ship *India*, built by Messrs. William Denny & Brothers of Dumbarton, which went ashore somewhere near the mouth of the Thames in December 1881, and was left by the tide some considerable distance; her bottom, although forced up about three inches over a length of about 40 feet amidships, did not give way, and the vessel did not make a drop of water. Again, there are the well-known cases of the *Rotomahana*, which ran on a rock in New Zealand, and, in the opinion of every expert who saw her, must have gone to the bottom with great loss of life had she been built of iron instead of steel; and that of the *Storm Cock*, built by Messrs. Laird Brothers of Birkenhead, which struck on the Irish Coast, and must have gone to the bottom had she been built of iron instead of steel, for one of her plates was dashed in a distance of five inches, and yet the vessel did not make any water.

All these are facts, which should be recognised, at least by underwriters, in the shape of reduced premiums in favour of steel ships.

Next in importance comes the question of corrosion, and this no doubt holds very nearly the first, if not the first, place in the minds of shipowners at the present time. I do not know, indeed,

that the question has yet nearly reached a settlement. We have had divers papers and divers opinions on the subject; but I have not yet seen evidence sufficient to show that the difference in corrosion between steel and iron is sufficient to deter the progress of steel shipbuilding; at the same time it will require careful watching.

The valuable data laid before this Institute in 1881 by Mr. Parker, the chief engineer-surveyor to Lloyds', on the relative corrosion of iron and steel, is perhaps the most valuable experimental data in existence; but I should not be surprised if curious things yet arise in practice, especially in cases where steel ships are not carefully looked after. I remember seeing a case not very long ago on the Clyde, where lines of corrosion had passed so straight across several strakes of bottom-plating that some people were misled into the belief that the vessel had cracked. I saw it, and examined it carefully, and it was obviously corrosive, but I could not account satisfactorily to my own mind for the phenomenon. Another curious instance I saw not many months ago. It was the case of a steel ship which had been launched just six weeks and was then docked, to receive her engines and boilers; and although she had been carefully painted before launching, with a good composition specially chosen by the owners, many of the plates presented a most curious appearance of pitting. They were scattered about in some parts without any apparent connection, and in others, the little mole-hills of rust (if the term may be used) seemed to have an order of their own, either in curves or straight lines. I was so much struck with this case that I examined it very thoroughly, and as the rust dried in the little mounds I carefully scraped a number of them off with my knife without injuring the paint, showing that although the rust thrown out formed a little hemisphere of about $\frac{1}{4}$ inch in diameter, the hole in the paint was not more than the size of a pin's head, while in each case it was easy to pick out a little loose particle of black oxide embedded in a little pit in the plate, and you could almost see the galvanic action going on. Fortunately, it was arrested in time, without any real damage being done, and I have very little doubt in my own mind that it arose from the bottom being painted before the black oxide had been properly got off. In such a case, the best cure, I think,

would be to send the vessel on a voyage without any paint at all on the bottom, when a general rusting would probably take place without pitting, and then scrape and paint her on her return.

On the other hand, another case was examined by me where a steel vessel was immersed for some months under water, and in this instance the shell plating, although rusty all over, had not been pitted, but presented all the appearance that you expect to find in an iron ship.

The general conclusion I have come to is that, so far as corrosion is concerned, it is purely a question of care and maintenance, which will soon be thoroughly understood, and that this question will not and should not retard the progress of steel shipbuilding.

From the foregoing observations, it will be seen, I think, that in the direction of mild steel for shipbuilding purposes, a decided step has been made in advance, involving improvement in all directions as to the quality of our shipping. I speak now of steel such as is made in this country generally to fulfil the conditions of Lloyds' rules and Lloyds' tests. It is not likely, however, that we have come to the end of the matter, and it may be as well to consider for a moment what directions are open to us, and likely to lead to further improvements. It has been contended by many, and with some reason, that we could very well raise the principal limit of tensile strength from 31 to 33 and the lower limit up to, say, 30 tons, and still get a ductile material, fit for shipbuilding. This is quite possible; but then, are we to shut out from use for shipbuilding purposes steel such as is at present made, ranging between 26 and 30 tons, while on the other hand we are admitting iron that in many cases will not stand 20 tons? This seems to me to be quite out of the question.

There is, however, a further matter for consideration. To all appearance the basic Bessemer process of steel manufacture is capable of turning out a very cheap material, of an extremely ductile quality, with tensile strains as low as 24 tons, and perhaps lower. Here we approach iron, but with much greater uniformity; and a question which, it appears to me, will have to come up seriously in the immediate future is whether, instead of fixing, as at present, certain scantlings for certain ships in iron, and then allowing a fixed percentage for steel of a certain tensile strength, it

will not become imperatively necessary, as a matter of common sense and justice, to have a graduated percentage of reduction, from zero for iron, up to, say, 10, 15, 20, and 25 per cent. for the varying qualities of steel, in accordance with their varying strengths, so long as the material itself, in all the grades, is absolutely fit for shipbuilding purposes in point of ductility and every other quality. This, I know, will require very careful handling, and I doubt if it will be accepted immediately; but it seems to me to be what we have before us, and I am not so sure that as we perfect our organisations we shall not be able to do what civil engineers and others feel themselves free to do—viz., to put in stronger descriptions of material in places where severe tensile strains are taken in ships, and to put in softer and thicker materials in places subject to local strains and removed from the severer tensile strains. I would much like to hear the views of those better acquainted with the probability of these softer steels being made cheap by the basic process, and also what are the chances of equally mild and ductile material being made equally cheap by the Siemens-Martin and Bessemer processes. These are points to which I can only refer with a view of obtaining information.

I have dwelt so long upon the quality of material that I fear I should be trespassing on your time if I were to do more than briefly indicate the principal directions in which improvements in shipbuilding have been taking place of late years, apart from the quality of material. The greatest change which has taken place is unquestionably the large adoption of steel; but besides this, much attention has been paid of late years to the longitudinal strains of very large ships, and much greater use has been made for this purpose of iron decks, longitudinal stringers in the bottom, and additional rivetting of the bolts.

In 1874 I was able to show, in a paper I then read before the Institution of Naval Architects, that as vessels increased in size from 100 tons up to 3000 tons, they grew weaker in almost regular progression to the extent of between four and five times, and that the larger ones were bordering on unsafety; but such a sweeping charge could not be made at the present time against the ships of the mercantile marine, even when we get up to 6000, 7000, or 8000 tons.

Next in importance to this great improvement is the introduc-

tion of cellular double bottoms, and the large use of web frames, for the purpose of giving additional transverse strength, and oftentimes in substitution for hold beams.

Further improvements in the way of water-tight bulkheads have been introduced, and many improvements of a minor character, for the purpose of giving greater safety to the deck openings, have been sometimes adopted voluntarily by the builders, and at other times enforced by Lloyds'.

Beyond this perhaps the greatest improvements have taken place in the internal fittings and decorations of passenger steamers, and in the adoption of electric lighting and other means for promoting the comfort of passengers.

In naval architecture, pure and simple, many improved methods and appliances have come into use for estimating and recording the stability and speed of ships; and progress in these directions, especially in the direction of stability, has been very marked within the last year.

I mentioned in the early part of this paper that one of the most marked features is the progress now being made with the marine engine, arising from the rapid adoption of very high pressure and extended expansion beyond the ordinary compound engines, where there are only two expansions. We are at the present moment building two sets of engines—one on the triple-expansion principle with 150 lbs. pressure, and the other with quadruple expansions, or 4 cylinders expanding into each other, and 160 lbs. pressure; and it is scarcely too much to say that we have a right to expect at least 20 per cent. saving in fuel over the ordinary compound engine. Triple expansion has been adopted by several firms for some time past. I do not know whether any besides ourselves have started quadruple expansion.

To deal with these pressures at all, the introduction of steel in the construction of boilers was an absolute necessity, and I do not think we have come to the end of our improvements in that direction.

In our own town, we have appliances now being laid down by the Vulcan Steel and Forge Company for rolling boiler-plates in continuous rings, and doing away with the longitudinal seams in the boilers; and every one will agree, I think, that when this is accomplished, a further marked increase of pressure and

economy will be brought about without undue thickness of boiler shells.

There is only one other point I wish to dwell upon—viz., the large introduction of steel castings into shipbuilding and engine works. Our ordinary and standard practice is to make reversing links, eccentric rod-ends, reversing levers, and link-blocks of cast steel, and the bulk of these have been supplied to us by the Steel Company of Scotland. They have proved of excellent quality, sound and tough, and have, whenever so required, been capable of being machined about all over with an almost entire freedom from air-holes. These parts are shown on the accompanying diagrams. Recently we have constructed a set of engines which were provided with Joy's valve gear, as shown on diagrams, and for this the working parts were made entirely of cast steel, thus avoiding most difficult and expensive forgings. Altogether we have used steel castings in our engines, to the extent above mentioned, for about two years.

In addition to this, I look forward with confidence to the large introduction of steel castings for rudder and propeller frames and stems, and many important ship-fittings, and I believe they will be a great improvement upon the large iron forgings, often with imperfect welds, with which we have been accustomed to deal, and a great saving of cost, with equal efficiency, in the smaller ones. I have shown a couple of diagrams of such castings now in use made by Messrs. Jessop & Sons, who deserve credit for having pushed this matter so vigorously.

In conclusion, I can only express the hope that the absence of startling statistics from my paper has not been a source of disappointment to the meeting, but that, on the contrary, the fact of steel for shipbuilding purposes having ceased for the time to be a burning question, may be a source of gratification to us all.

DISCUSSION.

Mr. MARTELL said he had very little to say on the subject of Mr. John's paper. He was not aware what the subject of it was to be, and had his name not been imported into it, he did not know that he should have said anything upon it. He agreed perfectly in the conclusion at which Mr. John had arrived, that mild steel had now passed out of the experimental stage into that of perfect certainty as to its fitness for shipbuilding, and he looked forward to the time when it would entirely supersede iron for shipbuilding purposes. They knew that it could be made of a perfectly reliable character, infinitely superior in every respect to iron, not only as to its ductility, but also, as experience appeared to be showing, in regard to durability. As an instance of that, which was certainly a striking one, one of the earliest steel vessels was built on the Tyne about six years ago, in 1878, when steel first came into use for shipbuilding purposes, and during these six years she had been engaged in the ore trade, running between Bilbao and the Tyne. No exceptional care had been taken of her, so far as he was aware, any more than of any other vessel, but she had been thoroughly examined inside and out, and the report of the surveyor was that the vessel did not show any symptom of deterioration whatever. That was a very gratifying result. As far as deterioration went, he believed with Mr. John that there was still a strong impression in the minds of many shipowners that in ships steel did deteriorate much more rapidly than iron, and that deterred many shipbuilders from adopting steel in preference to iron. He thought that an instance of that kind occurring in practical experience would do a great deal to disabuse the minds of those who entertained the view to which he had referred.

At the same time he quite agreed that this question would have to be carefully watched. With reference to Mr. John's allusion to the unsatisfactory state of some steel that had been used on the Continent, he had requested him (Mr. Martell) to give them some explanation. This case was rather interesting on account of what it had led to. There were two vessels build-

ing at Vegasack, a port in Germany; and they had a report from their surveyor to the effect that the steel was showing symptoms of cracking to a considerable extent, but he could not understand the cause. Under those circumstances Mr. Martell went to see the vessels, and in one of them he found as many as fifty or sixty frames cracked throughout. He had two or three frames heated in the furnace and turned in his presence to see whether it was owing to the manipulation, and whether the steel had been unfairly treated in any way. It was turned in the ordinary way, just the same as an iron frame would be, and he found that when it began to cool about the bilge it immediately cracked like the others. Three were tried, and all of them cracked more or less. Under those circumstances, he thought the best way would be to go to the works where the steel was manufactured. He went there, and found that the manufacturer was so impressed with what had occurred that he had heated several of the frames, and had turned them most carefully, believing the failures were owing to their being hammered; and it was found that they cracked in the same manner. Mr. Martell then found that the steel had been produced by the *basic* process, and the maker concluded that it was owing to the use of that process that he was unable to get steel of the reliable character required. He consequently wrote a letter to the effect that for the remainder of the steel he had to supply he would only use steel made by the ordinary Siemens-Martin process, as he had not sufficient confidence in the steel made by the basic process for shipbuilding purposes. That, of course, was a serious matter. Mr. Martell visited one or two other works in Germany, and saw several manufacturers of great experience, who gave him their opinion that steel basic could be made by the basic process with perfect reliability, and that if the actual cause could be traced, it would be found that the defect was owing to some deficiency in the knowledge of those who made the steel, and not to any particular inherent defect in the process itself. One, indeed, stated that he was building works that would cost £50,000 for the purpose of manufacturing steel by that process, which, he said, indicated the confidence he felt in it. On Mr. Martell's return home — the new works at Middlesbrough being about to supply some steel by the basic process for building ships to be classed in Lloyds' register—

their committee directed their officers to proceed to Middlesbrough and make a thorough test of the steel being manufactured there at the North-Eastern Steel Works. That was done, and the result was most satisfactory. It was found by the most complete tests that the steel was of a most reliable character. It could be made of the highest tensile strength as reliably as at the lower tensile strength. In fact, the experiments in question were altogether so satisfactory that the committee of Lloyds' Register could not do otherwise than place the description of steel made by the basic process on the same footing as that made by any other process. Such had been the result of the investigation. Since then he had had sufficient evidence to convince him that it was not owing to the process by which the steel was made, but that it was owing to the want of proper skill in the manufacturer who made the steel, that the failures to which he had referred had taken place. There had been whispers—he did not know whether there was any truth in them—that basic steel could be made very much cheaper than that made by other processes, and that there was a probability of its competing with iron in price. He only hoped that it would be so; and if steel could be produced generally by that process, such as that which had been tested and found to be of so reliable a character, he hoped to see the day, and that shortly, when it would entirely supersede iron for shipbuilding purposes. He might be permitted to say a word or two with reference to Mr. John's suggestions as to the use of steels of different strength. Theoretically, that, of course, would be very desirable, and he wished it could be done. But the practical difficulties would be very great. Shipowners like those on the Clyde, who ordered steel through their agents, would find it very difficult. They would get steel sent in of all varieties of strength; and he did not think that they could keep the different batches separate, or that they could say for certain that one was 33 tons and the other only 26. There would be a great practical difficulty in keeping them apart, and unless the thing was done with very great care it would not be done with safety. He had a very strong opinion that steel ships should only be built by experienced shipbuilders. Where there were smaller scantlings, thinner plates, and so on, the greatest care should be taken to fit them closely together. He

believed that the symptoms of weakness that had been observed in some steel ships, and similarly unsatisfactory symptoms, had, in the majority of instances, been caused by bad workmanship, bad fitting of butts, bad laying up, bad rivetting, and the like; and those who intended to build ships should have it impressed upon them, as a matter of essential importance, that the workmanship should be of the best character. More attention should be paid to that in steel vessels even than in the case of iron.

Mr. Jeremiah Head said that he felt a certain amount of diffidence in taking part in the discussion. Being a manufacturer of a material competing with that advocated, namely, shipbuilding iron, he might possibly be suspected of bias. But he was an engineer before he was an iron manufacturer, and he was reluctant to think he could only see from a self-interested point of view. At all events, he hoped his possible bias in one direction would do no more than neutralise the possible bias of others in an opposite direction. There could be no question that steel for shipbuilding purposes was making progress. But it had not yet superseded iron in any degree. For official statistics showed that there was more iron used for shipbuilding last year than during any previous year. Therefore, whatever progress might have been made with steel, it was entirely on the top of iron, and not, so far, in place of it. Iron manufacturers would, however, be extremely foolish if they shut their eyes to the probabilities of the future. If they were wise they would keep their eyes open, and so arrange matters that, if the world wanted steel rather than iron, they would be able to supply it. They should only seek to supply iron so long as the world wanted it rather than steel. They should not attempt to force matters, but simply adapt themselves to the requirements of the market. His firm had been for the last few years making steel plates in small quantities. They had most frequently purchased their blooms either from the North-Eastern Steel Company, who employed the basic Bessemer process, or from the Darlington Steel Company, who employed the acid Bessemer process. It was, of course, a matter of great interest to Clevelanders to consider how the change from iron to steel, when it came, could best be carried out. As far as he could see, their course was not yet at all clear. The steel for ship-

building which was so much in vogue, and which had been so highly spoken of, had up to the present time been almost exclusively made by the Siemens process. The material used was confined to the purest pig-iron and the purest ores. That was the first source of heavy cost. The blooms had been so far in all cases hammered, which was another great source of expense. The expensive material and expensive processes accounted mostly for the difference in price between shipbuilding steel and rail steel. The question had again and again been asked—How is it that when steel rails are made so extremely cheap, that steel ship plates yet remained, as Mr. John had shown, £2, 4s. above the price of iron plates? And how is it that the difference between iron and steel had not altered much, though the market prices of both had varied greatly? Probably the reason was that up to the present time only steel made by the more expensive processes, and of the more expensive materials, had been used for that purpose. He did not suppose, however, that the manufacturers of Cleveland intended to allow their immense stores of native ironstone to remain unutilised for the purpose of making shipbuilding steel. At present it was only being utilised for any kind of steel by means of the basic Bessemer process. But the question arose whether it could not be also utilised by an adaptation of a basic lining to a Siemens melting furnace. This problem was not as yet fully worked out. Mr. Gilchrist had told him that there were one or two firms making experiments in the direction indicated; and he was sure they would all watch with great interest the success of those operations. If steel was only to be made out of inferior pig-iron by the basic Bessemer process, commercial success could only be expected where it was made in large quantities. That was not always desirable. There seemed to be some very marked advantages in the Siemens process, where it was desired to manipulate smaller quantities, and ingots of various sizes, as for making steel plates. The Siemens furnace also gave great power of regulating the temper of the metal according to the purpose for which the steel was intended.

Again, there was the question to which he had just alluded, namely, whether the hammering of ingots could be got rid of or not. At present they were all hammered, and were cut under the

hammer to the size required. That was a rather wasteful, costly, and cumbrous process, and the question was whether blooming or cogging, with subsequent shearing or sawing, could not be substituted advantageously for this hammering; or, better still, whether the ingots could not be cleanly cast to the proper weights required, without any after-cutting. He thought that Mr. John, in speaking of iron plates, had been a little too severe. Even his own statistics only showed that one in 225 had failed. Well, that did not seem to be a very large proportion under all the circumstances. But he had gone on to say he had had experience of whole strakes failing, and so on. In that respect he thought he had been singularly unfortunate, and could only suppose that he had been buying in the very cheapest market he could find. With regard to labour uselessly expended on defective plates, Mr. Head's own firm were always willing to take the risk of paying for any such labour (which Mr. John spoke of as being rather a considerable item) for an extra 4d. per ton; —that was to say, if any one would give them 4d. per ton more, they would always take the risk of paying for any labour that might be expended on returned plates, besides replacing them. The question of corrosion had been mentioned. He gathered from the paper that Mr. John rather accepted the views and statistics given by Mr. Parker in a paper he read some time since before the Institute. The two principal papers on that subject, which he had himself read very carefully, were the one by Mr. Parker, and a previous one by Mr. Phillips. In both these papers the statistics showed that steel plates exposed to a moist atmosphere, or to the action of sea-water, corroded very considerably more rapidly than common iron plates, but not more than plates of a very high quality, such as those of Low Moor. The most favourable results were from common iron plates, which, in Mr. Parker's case, were stated to have been obtained from the Skerne Ironworks at Darlington. The average percentage was something like 19 per cent. in favour of common iron and against mild steel. It seemed to him that that result might have been expected beforehand. They all knew that the purer any metal was to which oxygen had an affinity, the less there was in the way of that oxygen rapidly uniting with it; and inasmuch as mild steel was very nearly pure iron, one would expect to find

that it oxidised more rapidly than common iron, which was mixed throughout with cinder. That cinder was a silicate of iron, a material which was in a stable chemical condition, or, in other words, as highly oxidised as it could be. They might, therefore, look upon common iron as a material in which all the fibres were painted throughout, which was by no means the case with mild steel or pure iron. In support of that view, he might call their attention to the fact that there were ships still existing which were built of iron as far back as 1845. The *Great Britain* steamship, built at Bristol in 1845, thirty-nine years ago, was still in existence. The *John Bowes* steam collier, built in 1851, thirty-three years ago, was still afloat on the Tyne. The late Mr. Henry Chapham told him that he had had a ship built in 1854, which was thoroughly examined two or three years since with a view to being re-classed at Lloyds'. Something like 1200 holes were drilled in this vessel in different parts to ascertain whether the thickness of the plates had diminished at all. The result was that, with the exception of about half-a-dozen plates, which had been corroded owing to leakages, and which were replaced, they could not find that there was any difference whatever in the thickness of the plate.

No doubt prevention of corrosion was to a great extent a matter of painting. They might have a corrodable material, but if they could get it painted before any oxidation commenced, and if they could renew the paint from time to time, he supposed it did not very much matter how corrodable the material might be. But taking a piece of naked iron plate and a similar piece of steel plate, as far as the evidence at present went, the steel was the much more corrodable material of the two. And he thought that *à priori* it might be expected to be so. The great advantage of mild steel seemed to be its capability of being worked cold. If there were no roughly sheared edges, and no other defects to begin with when it was cold, it did wonderful things. It certainly beat iron cold, and that was the great benefit that had been relied upon in the cases brought forward by Mr. John, such as ships bumping about on rocks. When they came to deal with steel hot, it was different in its character from iron. Of course it was only the somewhat higher qualities of iron that they usually sought to flange, and work hot to any considerable extent. Now, if iron when worked hot

was not up to the mark, or was defective in any way, it generally showed it pretty early. It would not flange at all, or it revealed scabs or other defects. But if they got it firm into the shape that they wanted it, they might rely on having no after trouble with it. Now that was not always so with steel. Only a week or two since his firm had made two boiler-ends for a customer abroad. They were dished and flanged all round. The steel for these boiler ends was rolled at the works of Mr. Head's firm out of ingots that they had purchased. The ingot bore rolling into blooms, and again into plates, perfectly well. They flanged perfectly without any trouble whatever; but on their arriving at their destination there was found to be a fine crack down each of the flanges, and they were returned and had to be replaced. Now, he admitted that that might have been a fault on their own part in not having annealed them after they were flanged. He believed, indeed, that annealing would have obviated the difficulty. But the point of his observations was this, viz., that such a disappointing, and, he might say, treacherous, result would never have occurred had they been made of iron, even though unannealed. Then, again, there were certain plates which were ordered from his firm for boiler-fronts for flanging at the ends. They were ordered of treble-best iron. His firm induced the customer to have them made of steel. The plates were $\frac{3}{4}$ inch thick; they rolled them of steel, and they seemed to be perfect. They were sent away, but were afterwards returned as having cracked spontaneously after flanging.

Mr. J. Riley—Can you tell me where the crack was, please?

Mr. Head could not say; he did not see the plates afterwards, but he knew that they failed in the way he had stated, and had to be replaced. He attributed the failure to their having been rather thick plates, and therefore having insufficient work upon them. They had at present an order for some considerable quantity of steel-ship plates, and had arranged with the North-Eastern Company to supply the ingots to pass Lloyds' tests. But Mr. Cooper made a proviso, in accepting this order, that none of the plates should be more than half an inch thick. Now, all that seemed to point to the fact that there was admittedly much more danger of spontaneous cracking with thicker steel plates

than with thinner ones. The quantity of work seemed to have a great deal to do with it. If the plates were thick, and therefore had not a certain amount of work upon them, they were not so reliable as if they were thinner. He supposed the cure was to make thick plates from ingots of a very much larger size, and so to put the work upon them. In conclusion, he could only say that this was a matter of very great interest to iron men, as well as to steel men. The iron men of the present might probably be the steel men of the immediate future. It was, therefore, their duty, as well as their interest, to watch closely the progressive requirements of the industry with which they were connected, and to do what they could to adapt themselves to it and aid in it.

Mr. J. Riley said he had almost got into the condition of imagining that steel had passed through the experimental stage; but perhaps it was as well for one to come there and have his mind disabused somewhat of that impression. At all events, it was gratifying to those who had struggled through the past years, after all the troubles they had had with the Registers and others, to listen to such a paper as that which Mr. John had read, showing the progress that had been made. Hearing Mr. Head speak, however, had almost carried Mr. Riley back about four years, Mr. Head having brought up questions which he thought had been settled, possibly for ever, and having stated them as though he were perfectly oblivious of what had been read and said at all the different Institutions in London. Mr. Riley knew that Mr. Head was not unaware of these points, and he could not quite understand why questions which he assumed had been settled, should be again raised. As they might suppose, he had been particularly pleased, on account of his own personal views, with the paper which Mr. John had read, and also on account of Mr. John having brought together so much evidence of the progress which had been made in the use of steel, and the steps by which they had arrived at their present position. Mr. John, in his paper, had first glanced at the question of testing, in its bearing on the settlement of the very much disputed point as to where the testing should be done—whether at the works or in the shipbuilders' yards—and undoubtedly the concession that had been made to them by the different Registers had been of immense

importance to them. At present they had only one slight grievance in that direction.

That splendid material, as Mr. Martell was accustomed to call it, was tested very severely by the Registers, but who would pass the iron plates which behaved so curiously that whole strakes, according to Mr. John, were sometimes condemned for imperfections after they had been passed through the works and been put on to the ship—being rejected for flaws which might have been observed at the works? He felt it was only common justice to so large and influential an interest as the mild-steel business had become and was becoming, that that more unreliable material—the one which was so treacherous—namely, iron, should also be tested. Why should they suffer all this expense, and be placed at this disadvantage, with a material which had been proved to be so trustworthy and safe in the instances of the *Duke of Westminster*, and the *Rotomahana*, and the other vessels which had been tried in the fashion described? Why should steel be tested with such extreme rigour, when no test at all was applied to the iron employed in the building of vessels? Surely the testimony of Mr. John, Mr. Martell, Mr. Denny, and other people who were using steel in the large quantity which had been referred to by Mr. John—so that even the workmen preferred to take up steel and work it in preference to working iron—should be sufficient evidence to Mr. Head that with ordinary manipulation and care those plates could be made to do anything and stand anything. Whilst Mr. Head was speaking of the two solitary cases he had had, Mr. Riley was reminded of his own experience in the years that had gone by. In almost every case where they had sent out plates to be worked for boiler purposes by a firm who had not previously used steel, they had had to make their calculation that one or two plates would be spoiled. They used, however, to say nothing about it except this, "It is a lesson: you have yet to learn how to deal with it." After a trial or two such as that, no more was heard of failures; but in almost every new case of commencing to work steel they had had to go through that experience. Mr. Head was going through that experience late in the day. Coming to the question of the cost of steel ships as compared with iron ships, Mr. John's paper was a most important one, as showing that they had almost arrived at the stage where smaller

vessels, carrying the same tonnage, could be built at the same cost in the one metal as in the other. Some six or nine months ago he was informed by one of the most eminent shipbuilders on the Clyde that they were prepared to give the choice to the shipowner to take the vessel in steel or in iron at the same money. In the case of a vessel of 4000 tons or upwards they undertook to do that, but there was a difference in the first cost for smaller vessels. Mr. John had shown that even that difference was being wiped away, and Mr. Riley was in a certain sense sorry to find that they were even now approaching the level where steel vessels of all sizes could be built for the same first cost as iron vessels, the tonnage being equal. Regarding the question of allowing differences of quality corresponding to differences of strength, Mr. Martell had taken up the position which it was probable he would take up. Mr. Riley thought it could hardly be expected that Lloyds' would agree to such possibly disturbing causes, if a large range of strength were allowed in the way suggested by Mr. John. He thought that some such arrangement would inevitably come, but as Mr. Martell had said, it must be done very carefully and very cautiously. It struck Mr. Riley that the margin of strength within which they had been accustomed to work should be maintained; but it did, perhaps, seem that some classes of steel were better adapted for certain purposes than others. Coming now to the end of the paper, he wished to remark upon the question of castings. This was so fully discussed at their last meeting that little more need be said; but during the last twelve months a very great step in advance had undoubtedly been made. His firm was now making sterns for war vessels of most peculiar shapes, which could scarcely be attempted in iron or other metals except at tremendous cost. They were being made as castings. Stern-frames, which, as they knew, had been made for two or three years similar to those represented in the diagram, were now being made up to eight and ten tons weight; and arrangements were now being made (mechanical arrangements such as would delight the heart of his friend Mr. Walker) which would enable very much larger castings to be dealt with. Now he came to the question raised by Mr. Head and referred to by Mr. Walker. Mr. Walker was usually given to being complimentary, but as

Mr. Riley sat in his place he felt as if some of them were rather receiving a castigation. It was, according to Mr. Walker's view, owing to the want of mechanical appliances that they were unable to produce steel plates cheaper. Now that was not the case. It might be that it was the case to a certain extent, but the fact was that it seemed to be a necessity, so far as Mr. Riley knew at present, that the ingot should be hammered or cogged previously to being rolled into a steel plate. In the struggle which they had had for seven years to make steel plates as relatively cheap as iron, the fact could not have been overlooked that one great source of cost was the hammering that the ingot had to undergo. During the seven or eight years which he had spent in working at this matter, he should think that he had made 800 or 1000 tons of plates which had not been hammered or cogged; the endeavour having been to roll a plate, as their friend said the rail was rolled, direct from the ingot. But the percentage of rejections and the failures were so heavy that the cost in that way was greater than the cost of hammering or of cogging. He used the terms hammering or cogging indifferently. At his works they had now turned out some thousands of tons of cogged plates, as well as plates made by the process of hammering; and arrangements were then being made by which pretty nearly the whole of the plates would be cogged. Various means had been adopted in the endeavour to roll a plate direct from the ingot. Different modes of heating had been tried. They wondered whether the modes of heating had anything to do with the surface defects, which were so prevalent in plates rolled off. Possibly there might have been some cause of defect there; but that was not the sole explanation. Then they turned their attention to the making of solid ingots—solid in the sense of being free from blow-holes. The result of that effort was that when the ingot was made perfectly solid, in the sense of being without blow-holes, which could be regularly accomplished, then what they were all well acquainted with, viz., "piping," was set up; and, as an inevitable consequence, the plate was what was called laminated, and it was this that he thought his friend Mr. Head had come across when Mr. Riley asked him as to the direction of the crack he had spoken about. Now they found themselves at present on the horns of a dilemma. Should they

have slightly honeycombed ingots, which they knew would make perfect plates when properly treated, or should they have ingots which were "piped," as the result of having been made solid? The danger in the latter case seemed to be so great that that had to be given up. More recently they had turned their attention to efforts to get over the "piping;" and he believed it was possible that that could be accomplished. But they had to depend so much upon the workmen employed in overcoming the piping, that the risk was greater than he cared to undertake. They had not attained to the position they held in regard to steel plates without very great care; and he did not care to risk that position for the sake of saving a few shillings per ton in the cost of making plates. The few instances of failure referred to by Mr. Martell brought to his mind one single fact of importance. During the last eighteen months they had shipped something like 12,000 tons of plates and angles to a foreign government; and not one complaint had reached them as to the working of any single bar or plate; neither had there been a single rejection of either plate or bar out of the whole of that quantity. That was a fact which might perhaps be set against the one or two difficulties to which Mr. Head referred. They had rolled over the whole of last year a thousand tons of plates per week—not reckoning the bars, but plates alone; and as to the failures—well, one's memory was apt to betray one occasionally, but he did not remember that they had had any outside failures, condemnations, or rejections out of the whole of that quantity. Coming to the question of corrosion, which he had almost forgotten, they seldom heard so much as a whisper of it. Until to-day he did not think that the term "corrosion" had been used in his presence and hearing for two years, at all events. The fact was that Mr. Head's statements were answered before he had spoken by Mr. Martell. Mr. Riley believed that the vessel referred to by Mr. Head was owned by a gentleman named Mr. Clapham. Was not that the fact?

Mr. Martell—Yes.

Mr. Riley said he thought as much. That vessel had been six years at sea, and she came into port and was thoroughly ex-

amined in every part, and not a single thing could be found wrong with her. Yet Mr. Head went back to a number of experiments which were seriously questioned at the time—those of Mr. Phillips. Mr. Head, referring to those experiments, said that the question of corrosion was not settled at all, but Mr. Riley took Mr. Martell to be a safer guide than Mr. Head.

Mr. WINDSOR RICHARDS referred Mr. Riley to a question on page 10 of Mr. John's paper, where the author, after referring to the inequality of the steel, asked what was the effect of successive heating upon that metal. If Mr. Riley would be good enough to give his experience on that matter, it might throw some light upon the occasional cracking of the plates, where people had inefficient methods of dealing with large ingots.

Mr. RILEY said he was afraid he could not explain the matter in the way Mr. John had referred to it. But he took it that one principal cause of danger was working at too low a temperature. If worked cool, it was perfectly safe; they might depend upon it fully, and do anything with it. Even at a pretty high temperature it was tolerably safe to work it, but, as was well known, with a black or a blue heat there was risk. They would then probably find that the plates would fail them. He could not quite explain the fact; the matter had not come before him in the precise form in which Mr. John had brought it up that day, and therefore he could not deal with it.

Mr. COCHRANE asked if Mr. Riley would refer to the question in the previous sentence, where Mr. John had spoken of the effect of holes being punched in the material?

Mr. RILEY said he immediately set that down to bad manipulation on the part of the people who were dealing with the plates. If the shears were not in good order, the plates would inevitably be spoiled. A great number of cases of that kind had occurred within his own experience. The effect produced by punching, with which Mr. John was perfectly acquainted, was produced in the same way when the shears were blunt or when the shears were not properly placed in relation to each other.

Mr. HEAD wished to ask Mr. Riley whether he utterly repudiated the experiments on corrosion of Mr. Parker, in the same way that he repudiated those of Mr. Phillips?

Mr. RILEY replied that what he had said was, that the experiments of Mr. Phillips were very strongly questioned at the time that they were produced or brought before the public. He had not referred to Mr. Parker, because he knew that his experiments were more carefully conducted than were those of Mr. Phillips; but this Mr. Riley did intend to have said: that he thought the result of the experiments was to prove that, although the corrosion of steel went on at a more rapid rate at the commencement of the experiments, yet, after a little time, the exact duration of which he had forgotten, the amount of the corrosion of the steel was not greater than that of the iron. That was also the result of experiments which had frequently been made by his own firm and by other people as well, who had corroborated the results at which he had himself arrived. He forgot whether Mr. Parker stated that, but the impression upon Mr. Riley's mind was that Mr. Parker's tables showed that result. At all events, such was really the case.

Mr. HEAD observed that the results of Mr. Parker's experiments almost entirely confirmed those arrived at by Mr. Phillips.

Sir HENRY BESSEMER, F.R.S., had not intended to address the meeting, but an observation which Mr. Riley had made induced him to say one or two words upon the subject. The great importance of perfect homogeneity in an ingot which was intended to be made into a plate had rendered it necessary, on almost all occasions, to either hammer it or cog it before rolling. Among the early experiments made by himself, and included in his very earliest patents, were two inventions closely connected with this subject, and which had been strangely, he might say wonderfully, neglected by the steel trade, who had so long had the right to use them without asking his leave or license to do so. One of these inventions related to the suppression of air-bubbles by hydraulic or atmospheric pressure. One of his earliest patents, now twenty-three years old, was taken out six years before the

date of Sir Joseph Whitworth's (and for that Sir Joseph took a license from him during the whole term of his patents), included a mode of applying hydraulic pressure to all ingots in the mould while the metal was still fluid. As they were aware, prior to solidification, all fluids capable of giving off vapour did so with a facility in proportion to the pressure to which they were subjected. He had found, by placing a crucible of molten steel in a close vessel, and communicating the interior of that vessel with another vessel quite exhausted of air, that immediately on thus removing the atmospheric pressure the metal in the crucible (which was about half filled) boiled so violently that eight-tenths of it came over the top of the crucible and fell into the vessel in which it was enclosed, thus showing how readily gaseous matters were evolved when freed from atmospheric pressure. By doubling or trebling the atmospheric pressure he had found that the metal ceased boiling, and he therefore included in his patent a method of generating gases under high pressure within a chamber in which the mould was placed. That process had been most successfully carried out at Sheffield, by Mr. Allen, within the last few years. He did not know that he was at liberty to tell them the whole of Mr. Allen's system; he thought it would be unfair to him to do so; and as he had on a former occasion read a paper before that Institute, Sir Henry had little doubt that Mr. Allen would be pleased to communicate to them the mode by which he had successfully produced ingots of absolute soundness without piping. Piping was a necessary consequence, under ordinary conditions, of the suppression of air-bubbles. Mr. Allen had not only suppressed air-bubbles, but he had suppressed piping. Sir Henry thought that that would have a most important bearing on the production of steel in the future. The other point to which he referred as having been so strangely neglected had reference to the mixing of the two metals which formed the ordinary Bessemer steel. When they had converted their metal into malleable iron, or as near an approach to it as possible, they put into it another metal totally different in its constituents, containing silicon, manganese, and carbon, and in the ordinary course of business they were content to simply pour one fluid into the other, as though that would produce an intimate mixture of those different metals. They would

not, however, let their grog stand without stirring it a dozen times with a spoon, because they knew it would mix much better by so doing. Then why did they expect that they could, both chemically and mechanically, combine those two foreign materials and make a perfectly homogeneous material by simply pouring one fluid into the other? Mr. Allen had for years used his (Sir Henry's) patent agitator for mixing, and the quieting of the metal was marvellous. The first rotation of the propeller threw off gas so violently that the ladle generally ran over. After two minutes' agitation, only a little blue flame of carbonic oxide issued from the surface, and then the metal became absolutely quiet. If the metal was thus quieted down by thorough admixture, and then submitted to pressure, solid ingots could easily be produced without piping, and these were the kind of ingots from which steel plates should be made.

Mr. Rogerson said that he had used boilers made of mild steel, manufactured by Attwood's process, at the Stanners Closes Steel Works, the plates having been rolled down from cast steel slabs without hammering. One such boiler had been in use at the works named upwards of 14 years, and was still working in good condition at the same pressure, viz., 50 lbs. per square inch. The plates in this boiler were $\frac{1}{4}$ inch thick, except the end plates, which were $\frac{1}{2}$ inch thick. The whole was doubly rivetted with steel rivets, and the holes were all drilled.

A boiler in the steamer *Wansbeck*, the plates, tubes, and stays of which were made of Attwood's steel—the plates being $\frac{5}{16}$ inch thick, and the tube plates $\frac{5}{8}$ inch thick, while the shell and furnaces were double rivetted with steel rivets and all holes drilled—was loaded to a pressure of 30 lbs. per square inch, and had been kept at work for 5 years. It has shown no signs of corrosion, and was still in good condition.

Steel made by Attwood's process had been used by the River Tyne Commissioners, the Tyne General Ferry Company, and others, on board steamers, in the form of castings and forgings, such as cross-heads, propellers, shafts, reversing levers, link blocks, pistons, &c., for the last 15 years, and no accident had occurred in breakage.

As regards corrosion, experiments were made at Tudhoe Iron-

works on specimens of iron and steel plates of the following chemical composition:—

	Mild Steel.	Medium Hard Steel.	Tudhoe Best Best Iron.	Tudhoe Crown Iron.	Common Iron.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Iron . . .	99·354	98·400	99·000	98·900	98·800
Carbon . .	·115	·330	Trace.	Trace.	Trace.
Manganese .	·504	1·008	·216	Trace.	Trace.
Silicon . .	·055	·065	·111	·107	·177
Sulphur . .	·028	·022	Trace.	Trace.	·008
Phosphorus .	·037	·075	·165	·217	·532
Copper . .	Trace.	Trace.	Nil.	Nil.	Nil.

These specimens were originally 2 inches square by $\frac{3}{8}$ inch thick, and had been immersed in a bath of water containing 1 per cent. of sulphuric acid, the loss in weight being recorded every twenty-four hours. The "mild" steel in seventeen days only lost 4·8 per cent. of its weight, while the iron samples in the same time lost from 34·7 to 79 per cent.

In the building of steamers for the Tyne General Ferry Company, it was necessary to have a light draught of water, with the greatest strength. For several years past the steamers had been built of Weardale steel plates of $\frac{3}{16}$ and $\frac{1}{4}$ inch in thickness; the total weight of steel being 30 tons per steamer. The steel was tested according to Lloyds' rules, and every plate, angle, &c., had an ultimate tensile strain of between 27 and 31 tons per square inch of section, and an elongation of not less than 20 per cent. in a length of 8 inches. The chemical composition of the steel was:—Iron, 99·375; carbon, ·110; manganese, ·400; silicon, ·028; sulphur, ·037; phosphorus, ·050; and copper, trace; total, 100·000. The boiler was also built of Weardale steel, of the same chemical composition as that used for the boat, and in accordance with the Board of Trade requirements, which in the case of boilers were, "that a strip cut from every plate shall stand an ultimate tensile strain of between 26 and 28 tons per square inch of section, and shall show an elongation of not less than 20 per cent. in a length of 10 inches."

The advantages to be obtained by the use of steel for marine purposes would be—decrease in weight, increase of strength, greater ductility, and, probably, extra durability.

As to the strength of steel vessels in collision, he might mention the case of the *Norman* (built of Weardale steel, made in the Bessemer converter erected in 1862), which had her stern bent over without a rivet being started. Had this vessel been built of *iron*, her plates would have split.

Mr. W. Putnam said this seemed to be a battle of platemakers, and he was a forged-iron manufacturer. A little had been said about iron forgings, but he could hardly discern the point of attack, because Mr. John simply gave it as an expression of his opinion. Mr. John referred to imperfect welding. He admitted that there had been a great deal of imperfect welding in many stern-frames. There had also been many bad castings. He should like the makers of these steel frames to honestly tell them, out of the number of frames they had turned out, how many bad ones they had made that the world knew nothing of. Steel was confined now to about three makers, all of whom, he believed, were present. Let them have the fact honestly out. He maintained that a large stern-frame of any size could be made perfectly sound in iron if it was properly made. Mr. Head gave the true test when he made a remark about buying in the cheapest market. He believed the whole question hinged on that. If shipbuilders, when they were ordering important pieces like large stern-frames, would give an order to the first man who came into the office and presented his card, without ascertaining whether he was in the position and capable of doing the work, and simply because his price was low, he must run the risk of bad work. When they attempted to stick large sections of iron together, 12 feet 6 inches or 15 feet by 7 inches, they wanted powerful appliances to do it, and the old-fashioned plan of simply making a butt-joint, or nearly a butt-joint, and merely gumming them together, would not do for the size of the present ones, and that was the cause of the failures. He might mention that the practice in his own place was to make them solid under the steam-hammer. He believed that had been seen by many of the gentlemen present. He would like to say a word also with reference to the use of steel forgings generally. It seemed to him that the Institute, to a great extent, became a great advertising medium. Much was heard in that room about successes.

During the last two years he had made large crank-shafts in iron for steel-makers, supplying seven of the largest steel-makers in the country with wrought-iron shafts. In some cases the wrought-iron shafts were to replace steel. He would give another case. If any one class was more interested than another in urging the use of steel, it should, he took it, be the people who got the most out of it, the steel-makers. Most of them would know that there was a vessel called the *Faraday*. She was fitted out with steel shafting. During the last six weeks, the *Faraday* had been put into dock; her steel shaft had been taken out, and an iron one had been made to replace it. Now, in the face of all this, seeing that the doctors would not take their own drugs, what were they to think? Many of those present knew that at the works in which he was interested they were quite as capable of making steel forgings as any firm in the kingdom. He thought their President would bear him out there, but it would be readily understood that, with all he saw before him, he himself had a weakness for iron, and until he could see that steel of a reliable quality was to be produced in large masses—and it was quite clear that the steel-makers themselves did not now think it could—he would keep off steel for the present.

Mr. Cooper said that having only just entered the room he was somewhat at a loss as to what he should say, but he observed this passage on page 16 of Mr. John's paper: "It has been contended, and with some reason, by many, that we could very well raise the principal limit of tensile strength from 31 to 33 tons, and the lower limit up to say 30, and still get a ductile material fit for shipbuilding." Mr. John then went on to state: "There is, however, a further matter for consideration. To all appearance the basic process is capable of turning out a very cheap material of an extremely ductile quality, with tensile strains as low as 24 tons, and perhaps lower;" and he reasoned from that, that inasmuch as by that process a material infinitely superior to iron was obtained, there should be a graduated percentage of reduction from zero for iron up to 25 per cent. for the varying qualities of steel. Mr. Cooper, whilst doubting the wisdom of the former part regarding the higher limit, agreed with the atter part of Mr. John's views on the matter, after the some six

or eight months' experience they had had with basic material for that purpose. The principal reason why steel for shipbuilding could not be produced at a much lower cost was that the restrictions imposed by Lloyds' at the present time were such that it was impossible to take the material direct from the Bessemer pit, and convert it into the finished article right away. If they could get a range varying from 23 or 24 tons to, say, 31 tons, with a 10 per cent. reduction of scantlings, he thought that that would be perfectly feasible, and the advantages would be that they would not only get perfectly rigid ships of an infinitely superior material, but he thought the time was not very far distant when they would be able to get, angle for angle and plate for plate, ships of that soft steel quite as cheap as the iron of to-day. There was just another question which he understood Mr. Head had raised. Mr. Cooper was not in the room at the time the question was put, but Mr. Head had asked why they (the North-Eastern Steel Company) had declined to supply slabs for plates thicker than half an inch. The reason was that up to the present time the ingots from which the slabs were made were only 11 inches in thickness, and he was afraid that the amount of work would not be sufficient for plates thicker than half an inch to insure perfect success. At the present time, they were laying themselves out to deal with larger ingots, and he thought the time was not very far distant when they would be able to make thicker plates quite as successfully as they had done, and were now doing, half-inch and even thinner ones.

Mr. Perry F. Nursey said there were two points in Mr. John's valuable and interesting paper which appeared to him to require a little further elucidation. One he thought Mr. John himself could elucidate; the other Mr. Nursey would endeavour to throw some further light upon. The first point occurred at page 9 of Mr. John's paper, where he said: "I have seen plates lose 30 per cent. in punching when they got above half an inch thickness." Of course they knew that with iron plates it was necessary to use very great care, and to put in good work, drilling being preferable to punching; but Mr. Nursey was of opinion that they had got over that difficulty by the more general introduction of steel. Therefore he would ask Mr. John if he would kindly state whether the whole plate lost 30 per cent. of its normal strength

— whether his tests showed that the loss extended over the whole plate, or whether the loss of strength was merely in the region of the holes. The second point to which Mr. Nursey wished to refer occurred at page 15, and was in respect of corrosion. Mr. John gave an instance of a Clyde-built steel vessel in which he found a very peculiar condition of things going on after she had been painted and launched. Little hillocks of oxide appeared to have been formed in curved and straight lines on the plates. It occurred to Mr. Nursey that it was very possible that that vessel was painted when the plates were damp or in a damp atmosphere, and that the regular or the curved and straight-lined appearance of the little hillocks of rust was simply due to the painter's brush carrying the moisture over a certain area of the plates in certain defined directions, and then imprisoning it under the paint. In course of time, the moisture acting on the iron caused the formation of the oxide, which eventually burst through the paint, and gave the peculiar result described by Mr. John. He felt rather diffident in offering a suggestion as to the remedy, because he did not think it right in a meeting of that kind to advertise any particular paint. He would, therefore, confine himself to the substance, without naming the inventor. Some sixteen or eighteen years ago he tested a certain paint, a Torbay oxide paint, of which there were several. With the experiments he then carefully carried out he found that this paint did form a most perfect protective covering. That was done by first bringing a mild oxide on the plate itself. He was referring to iron, and not to steel. He had since used that paint in some works with which he had been connected; and before applying it he had had the iron-work laid out during the night, and allowed it to get a mild rust upon it. It was then allowed to dry in the sun, the paint being afterwards applied. He had had occasion to examine some of the work thus treated about four months ago; and he found that the plates were as good and the iron-work as free from rust and scale as they were the day he laid the paint on. He, therefore, suggested that as a remedy, which seemed to coincide with Mr. John's idea of allowing a vessel to go a voyage, to get a little rust upon her plates. But it was necessary to let the plates get quite dry, and still more necessary was it to be careful as to what paint was applied.

Mr. P. C. Gilchrist said that, after the explanations which Mr. Martell had given as to the failure of basic steel abroad, there was nothing he need say upon that point. There was, however, one point in reference to which he wished to put a question to members. He would ask whether it was not the case that all steel, no matter how made, was more liable to be spoiled by cold rolling than iron was? He thought this would often arise from the fact that the iron plant which would roll steel slabs was accustomed to roll softer material (puddled bar piles), and that in consequence it frequently happened that more passes were given to the steel slab to finish it than would have been given to the iron pile, so that the steel plate was often finished very much colder (the speed of the engine being unaltered) than the iron plate. Unless precautions were taken to avoid this, the result would be that the steel plate would be sometimes brittle, as steel plates must be finished as hot as, if not hotter than, iron plates. With reference to Mr. Head's question as to basic Siemens steel, there were works in Russia running entirely on basic Siemens steel, and making about 500 tons a week from a mixture containing 1 per cent. of phosphorus. He presumed, as the whole of the works in question had been run on such steel for some time, that it gave every satisfaction. When Mr. Gilchrist was there last August, it was being used partly for rails and partly for angles and plates, and since then he thought it had been used even more largely for angles and plates. In reply to Mr. Richards' question, he might say that in North Wales soft steel had been made in a basic Siemens furnace from a pig containing 3 per cent. of phosphorus, and preparations were being made to produce a considerable weekly quantity of steel from such a pig.

Mr. Joy said that as Mr. John had referred in complimentary terms to some of the articles made on his system, where basic steel had been used, he thought he might say a word on the subject. Although his experience did not count in thousands of tons, but perhaps only in cwts., still it was in a different direction altogether from what they had heard of. They had heard of the resistance or the power of endurance of this material in a static condition. His experience had mostly been in the use of this steel in a very active condition of violent motion. Several of

the most advanced railway companies were using this material to produce castings, which would otherwise be very complicated and expensive forgings. If anything afforded a severe test of material, he thought it was exceedingly rapid revolution, and he was not aware that they had in any one case had the least bit of trouble with the material in question. They found no difficulty in getting any figures they liked, they found no difficulty in tooling the material, and they had not, so far, experienced the least difficulty from corrosion.

Mr. B. Walker said that if they attempted to roll Low Moor or Bowling plate, only drawing it in one direction, they would utterly fail; and if they attempted to put more work into the ingot end way on, they got the mechanical force and mechanical strain that were required to bring the particles into contact in order to make them uniform in quality. The reason why thin plates were more uniform was that they got more work than the thick plates. What was wanted was to give end pressure either by hydraulic pressure or by some other means, so as to bring the particles of steel more thoroughly into contact with each other. If any of the large firms would make steel plates in the same way that they made steel rails, it would be found that they could make them quite as cheaply as they made iron plates.

Mr. E. Windsor Richards (who was called to the chair in the compulsory absence of the President) observed that no matter how cheap steel or iron might be, they were always asked for cheaper steel or cheaper iron. Even that day Mr. John had been asking for cheaper material. Looking at the price at which iron plates could be bought at the present time, they knew that, with the exception of those makers who were best situated, little or no profit was realised. He was sure that most manufacturers were losing money by making iron plates, and yet the demand for cheaper plates continued, while on the other hand there were the most inconsistent complaints as to quality. Could they expect to get really good and carefully made iron plates that would stand punching and knocking about in shipyards at the wretched price that was being offered? Under the circumstances there

was no inducement to manufacturers to put up the large mills that had been suggested with a view to the cheaper rolling of plates. No doubt steel plates could be made cheaper by means of better appliances, and he thought they were not lacking in brains, as was suggested by Mr. Walker; it was money they wanted. Some years ago, he got out plans and estimates for a large mill for rolling ship plates. He had intended to roll them 100 feet long, and from 6 to 10 feet wide. On mentioning the matter to Mr. Riley, that gentleman predicted failure, on account of the impossibility of getting a steam hammer capable of dealing with so large an ingot. Mr. Richards then stated that he saw no difficulty in rolling and cogging an ingot that would give a clean surface plate, by constantly turning the ingot over. As they had rolls 4 feet in diameter in successful operation at Eston, why should they not have them of 6 feet or 8 feet if they liked? They need not be very heavy. The rolls at Eston were hollow. When the billet was first rolled the scale was squeezed into the surface of the plate, and then it was turned over the other way, and squeezed hard so as to bring it down a couple of inches at a time; the scale might be seen to drop off from the sides. If the bloom were rolled first on flat and then on edge, a very clean surface plate would result. The idea of making steel by the basic Siemens process had been started by Mr. Head saying that they would be looking to that system by and bye for making ship plates, using phosphoric ores and pig iron for the purpose. He did not think, however, that with the knowledge they now had they could look to the Siemens furnace for helping them in that direction. Very little phosphoric pig was being used in the Siemens basic furnace. He had reason to believe that not more than 20 per cent. of the charge in a Siemens furnace was phosphoric iron, the rest being made up of scrap containing no phosphorus. Mr. Richards concluded by asking the meeting to accord a hearty vote of thanks to Mr. John for his very able paper, and this having been accorded by acclamation,

Mr. John proceeded to reply upon the discussion. With reference to the remarks of Mr. Martell, he was sure they would all unite in thanking that gentleman for having given the results

of his investigations in Germany with reference to the failure of steel angles. As to having different allowances for different strengths of material, he did not expect that Mr. Martell would agree with him; but he, nevertheless, certainly thought that the time would come when they would have to get out of the slip-shod way now pursued in ship-yards—and encouraged, he was afraid, by surveyors and everybody else — of using material of all the same quality, whether it was to take a strain of 10 tons on the square inch, or only 10 cwt. The present system had the merit of simplicity, but it was, nevertheless, a barbarous one. With reference to the remarks of Mr. Head and Mr. Putnam as to people buying in the cheapest market, when quality was complained of, it was always said, "If you had paid a decent price, you would have got a decent material." Like everybody else, his firm bought in the cheapest market, where they had a right to expect that they would get good material, and no shipbuilder who had any sense at all would think of giving an order for heavy stern-frames, or for plates and angles, to people whom he thought incapable of turning out material of the quality he required. As to the loss by punching of which Mr. Nursey had spoken, the figure given, 20 per cent., was the loss of strength between the holes by punching. That figure was arrived at as the result of a number of experiments which were made under his inspection some years ago. In reference to pitting, he thought the explanation given by Mr. Nursey a very reasonable one, viz., that damp might have got in with the paint-brush, and been left under the paint. No doubt there must have been damp under the paint in little spots, whether left by the paint-brush or not, in order to set up oxidation, and galvanic action between the black oxide and the steel was set up, by which the paint was eventually burst, and these little molehills formed. The circumstance occurred in the summer of last year, and he believed that if the vessel had been painted in wet or wintry weather the difficulty would not have occurred. The plates, being exposed to the weather, would have rusted, and the black oxide would have gone off before the painting took place. Mr. Head, in speaking of corrosion, gave a very theoretical view of the matter, and spoke of the results of experiments make by Mr. Parker and Mr. Phillips, which were

all very well before people had got experience; but it was futile to set up experiments which were made on a small scale for the purpose of trying to foresee how steel ships would behave against the experience now gained from the 300,000 or 400,000 tons of steel shipping at present afloat, and telling their own tale. Mr. Head had stated that steel was homogeneous, and contained no impurities, and therefore that it was more likely to corrode than iron, which was more or less filled with impurities. From that it would be expected that steel would corrode uniformly, and that iron probably would not corrode uniformly. But, as a matter of fact, just the contrary was the case—the iron corroded with a fair degree of uniformity, while the steel pitted irregularly. Mr. Richards mentioned that shipbuilders were always asking for cheaper steel, and, at the same time, for better quality. He could only say that shipowners were always asking for cheaper ships. He was not sure that the pressure on the one side for cheaper ships, and on the other side for cheaper and better steel, did not produce a good effect. He was sure that it had produced a good effect, as they were now getting better steel, and getting it cheaper.

Mr. Lowthian Bell, F.R.S., proposed a vote of thanks "to the Council and Secretary of the Institution of Civil Engineers for the accommodation afforded to the members of the Iron and Steel Institute, and the facilities otherwise provided for that meeting," and the motion having been seconded, was carried unanimously.

Sir Henry Bessemer, F.R.S., said that before they separated, after that very interesting meeting, they had one little duty to perform which he was sure they would all agree to with great unanimity. He had the pleasure to propose a cordial vote of thanks to their President for the very able way in which he had conducted the business of the meeting from the first moment when he took the chair until he was obliged to vacate it rather hastily in order to attend to his parliamentary duties. He thought they might also include in that vote the Vice-President (Mr. Richards), who had so kindly taken his place upon that occasion.

Mr. JAS. RILEY seconded the motion, which was unanimously agreed to.

Mr. RICHARDS briefly thanked the members on behalf of the President and himself.

The proceedings then terminated.

In the course of the proceedings the President announced that the Council had elected Mr. James Riley, of the Steel Company of Scotland, to be one of their colleagues at the Council Board.

The following paper was taken as read :—

ON IMPROVEMENTS IN APPARATUS FOR GAS ANALYSIS.

By Mr. J. E. STEAD, Middlesbrough.

A New Form of Gas Apparatus for Testing Waste Gases from Boilers and Heating Stoves.—I have been repeatedly asked by some of our blast furnace managers in Cleveland, during the last few years, to design an apparatus which would rapidly and simply indicate when the waste gases from hot-blast stoves and boilers fired with gas were of proper constitution—that is to say, contained neither unburnt gas nor too large an excess of air.

After careful study and investigation, I have brought out the apparatus now before us.

It was found, by analysing a large number of samples of waste gas from stoves and boilers in the Cleveland district, that in nine cases out of ten a large excess of air was present.

As is very well known, perfectly burnt blast furnace gas contains only two so-called permanent gases, viz., nitrogen and carbonic acid. Water vapour is also present, but this condenses when the gas is cooled. When incompletely burnt, the unconsumed carbonic oxide passes on to the flue, and there burns if air finds access to it; but if not, it passes on up the chimney, and most frequently burns at the top. Such a state of things is readily detected without any further examination. When, however, air is present in excessive amount, its presence can only be detected by an analysis of the waste gases.

As a general rule, analysts in such a case would determine the amount of air by an estimation of the free oxygen, but as such an estimation requires a skilled analyst, advantage was taken of the fact that, on an average, perfectly burnt gas from

any given blast furnace contains a fairly constant quantity of carbonic acid, and that, by a simple determination of the quantity present (an operation performed in this new apparatus in about two minutes), an approximate estimation of the air might be made, the air present being considered as inversely proportional to the carbonic acid found. Thus, for instance, if the carbonic acid in perfectly burnt gas amounted to 25 per cent., and in a sample tested it was only $12\frac{1}{2}$ per cent., we would assume that the air present amounted to 50 per cent.

Having an average analysis of the gas from any blast furnace plant, it is easy to construct a scale which will indicate at once the excess of air.

I will now pass on to describe the apparatus. It will be seen from the diagram that it contains three essential parts. First, the gas-receiver B; second, the potash laboratory vessel G, which is in communication with the measuring tube (open to the air) H; and, thirdly, the mercury reservoir I.

The gas-receiver B, it will be noticed, is fitted with a three-way cock F, so arranged that by turning it in one direction a passage is effected to the tube A, which can be put in communication with the gas flue from which it is desired to draw a sample of gas, and by turning it 90° (in the opposite direction to the movement of a watch), it is brought into communication with the potash laboratory tube G.

At its lower extremity there is a branch C in communication with the suction tube D, and below this another tube communicating with the movable mercury reservoir I.

In using this apparatus we proceed as follows, viz.:—

Insert the end of the tube A in the flue from which it is desired to draw the gas, the position of the cock F being such that the red end points to the left. Then lower the mercury reservoir I to the bottom of the grove. This will cause the mercury to flow out of the vessel B, and from the suction tube D, until the passage C is clear. Then cause a stream of gas to flow through B by applying suction to the tube E. When all the air originally present in the tube connections has thus been eliminated, and the vessel B filled with the gas, turn the cock F so that the red end points downwards, and gently raise the mercury reservoir I. As this is raised the mercury will flow up to

the point C, cutting off communication with the tube D, and securing at the same time an exact measure of the gas in B; but as the mercury still flows upwards, the whole of the measured quantity is forced into the potash laboratory G, where the carbonic acid is absorbed. The potash displaced by the gas in the chamber G is forced up the tube H, and the height at which it stands, measured on the scale, indicates on one side the carbonic acid, and on the other the corresponding amount of air. The analysis will now be completed, and I think you will see that it must be a very expeditious method of procedure.

In preparing the apparatus for another determination, it is necessary first to turn the cock F to its original position with the red end pointing to the left, then to turn the cock J to allow the imprisoned gas remaining in the potash vessel to escape; and as soon as this is effected, to turn it back to its original position (the red end pointing to the right or left). When these simple matters of detail are completed—that is to say, when one tap has been turned once and another twice—it is ready again to proceed with as before described. When the apparatus is put away, care is taken to draw out the plug cocks and to drop them into the pockets prepared for them; for if this is not done, they sometimes stick fast, and cannot be removed without breaking the tubes.

In the apparatus specially arranged for the use of workmen or works-foremen, everything except the indiarubber tube is secured in a small portable case. The apparatus on the table before you is one of this description.

You will see that it contains everything needful for testing, except a small amount of human brain.

The case as it stands is ready packed, direct from the makers. It contains a bottle of potash 1·30 sp. gr., and a fine tube for filling the potash laboratory, a bottle of mercury, a small case of vaseline for smearing the taps, and a small pair of suction bellows for drawing or pumping the gas into the apparatus.

In examining the waste gases from boilers fired with coals, it has been found that the amount of air is generally in large excess, but that this fluctuates very considerably. When coal is first added, a very much larger quantity of air is required than at other times, and at this point the air has in some cases been

deficient; but on an average, over a period of time, it is generally largely in excess.

It is almost impossible to regulate with exactness the inlet of air to a boiler-fire fired with coal, but there can be no doubt that advantage must arise from several of the mechanical arrangements which have been designed for making such intermittent regulations.

The apparatus I have designed should, in the hands of mechanical engineers, be of great assistance in testing such mechanical contrivances.

In conclusion, I should point out that if gas or coal is supplied with an excessive amount of air, the intensity of the combustion will be reduced in proportion, and unless means are taken to again cool the hot air by some regenerative system, the effective power of the combustible will also be greatly reduced.

On Ammonia in Cleveland Blast Furnace Gas, and on a Special Form of Aspirator for Drawing off Gas in Making Ammonia Determinations.—During the last three months I have specially examined the gases from Cleveland blast furnaces, to ascertain if there was present in them sufficient ammonia to make its recovery a commercial object.

It is scarcely needful to explain the usual analytical methods for the determination of ammonia, as every analyst is familiar with them. I shall simply, therefore, describe how the ammonia was removed from the gas, the method used in drawing it through the absorption tube, and the results obtained.

The aspirator used was a modification of Mr. Dancer's reversible apparatus, but modified so as to meet the special demands. It consisted of two vessels, one over the other, each having a capacity a little over half a cubic foot. The two vessels have a communication between them, consisting of a tube and brass stopcock. There are openings at the top and bottom of each of the vessels, which are closed alternately.

In working with the apparatus, exactly half a cubic foot of water is measured and poured into the lower vessel through the hole D (see diagram). The indiarubber cork is removed from the opening C, and inserted into D. The tap E being closed, the whole apparatus is reversed, so that what was the bottom vessel becomes the

uppermost. An indiarubber tube is now fixed on the stop-cock B, and after opening it, and the stop-cock E, a steady flow of air or gas passes into the vessel. As soon as all the water has passed into the lower vessel the taps are closed, and the apparatus is reversed, after the indiarubber cork has been removed from D to C.

By removing the indiarubber tube from B to A, the gas may again be drawn into the vessel.

Careful notice is taken of the number of times the vessels are filled, as this is, of course, required when calculating out the results.

The tube inserted into the flue was of glass; it was covered at the end with asbestos and copper wire, and was caused to dip towards the absorption tube, so as to allow any ammonia water which might condense in the tube to run into the absorption apparatus. The latter consisted of a single six-inch U-tube, partly filled with broken glass, and moistened with hydrochloric acid.

The glass tube from the flue passed directly into one limb, and the indiarubber tube in communication with the aspirator was attached to the other.

The results obtained were as follows, viz.:—Ammonia per ton of pig metal, between 400 and 500 grains.

These results are what we might expect, considering the fact that Durham coke rarely contains more than 0·10 per cent. of nitrogen, although sometimes as high as 0·3 per cent.

On a New Form of Gas Sampler.—At a previous meeting of this Institute, I had the honour of bringing before your notice a new form of gas-testing apparatus. The sampler I now have the pleasure of describing is designed to work in conjunction with that apparatus, although it can, of course, be used with any other kind of gas-testing arrangement. It is made by Messrs. Mawson & Swan of Newcastle from my drawings, and is constructed in such a way that a sample may be taken by its means over any length of time, from one minute to twenty-four hours. When working slowly, in order to prevent diffusion occurring along the tube conveying the gas to the apparatus, a special mercury trap is arranged at the inlet branch, shown at the left-hand side of the diagram.

In taking a sample of gas, the whole arrangement is hung on the side of the flue from which the sample is to be drawn.

The mercury reservoir is raised and placed on the shelf B, and the taps C and D are opened.

The air in the vessel H, thus driven out, is completely replaced by mercury.

The tap C is now closed, and the reservoir lowered. The tube communicating with the flue is then connected to the limb E, and after opening the taps E and D, the gas is sucked right through the upper tubes, by which means any air is drawn out of these connections.

As soon as this is done, the tap D is closed, and the opening at the top of the reservoir A having been placed under the tap F, the latter is opened, and the mercury allowed to flow into A at any desired speed. As the quantity of gas flowing into the collector is the same as the quantity of mercury flowing out, it will be clear that the former can be regulated to the greatest exactness by measuring the mercury as it flows out in a graduated tube, noting the time required to pass 10 cc. mercury, and comparing this with the whole contents of the vessel H, and the period over which the sample is to be taken.

The sample, when complete, can be taken to the laboratory, the reservoir A placed upon B, and the tap C opened.

When the gas apparatus is ready to receive it, the tap D is opened, and after a certain amount of the gas has thoroughly expelled the air from the tube D, it is connected directly to the gas-testing apparatus, and the necessary quantity is drawn off for analysis.

In examining blast furnace flues, it is always found that, when taking an average sample, the amount of dust is so great that the ends of the small tubes inserted are frequently choked up. It has been my practice, therefore, to cover the end of the inserted tube with asbestos, and the asbestos with copper-wire gauze. By this means, although the gauze does get covered with dust, the gas passage is always maintained.

My friend Mr. Rochell has an objection to so many glass taps about this apparatus, and suggests that indiarubber tubes and screw clips would be far better. In order to conform with this

suggestion, it is only necessary to cut off the taps E and D, and substitute the indiarubber connection.

In the apparatus most recently made by Messrs. Mawson & Swan, the vessel H is firmly secured on the stand, and both the stands B and G are made into trays to prevent any loss of mercury.

As in all other glass gas apparatus, it is imperative that the taps be removed when not in use.

APPENDIX.

THE IRON AND STEEL INSTITUTE.

STATEMENT OF ACCOUNTS FOR THE YEAR ENDING DECEMBER 31, 1883.

RECEIPTS.

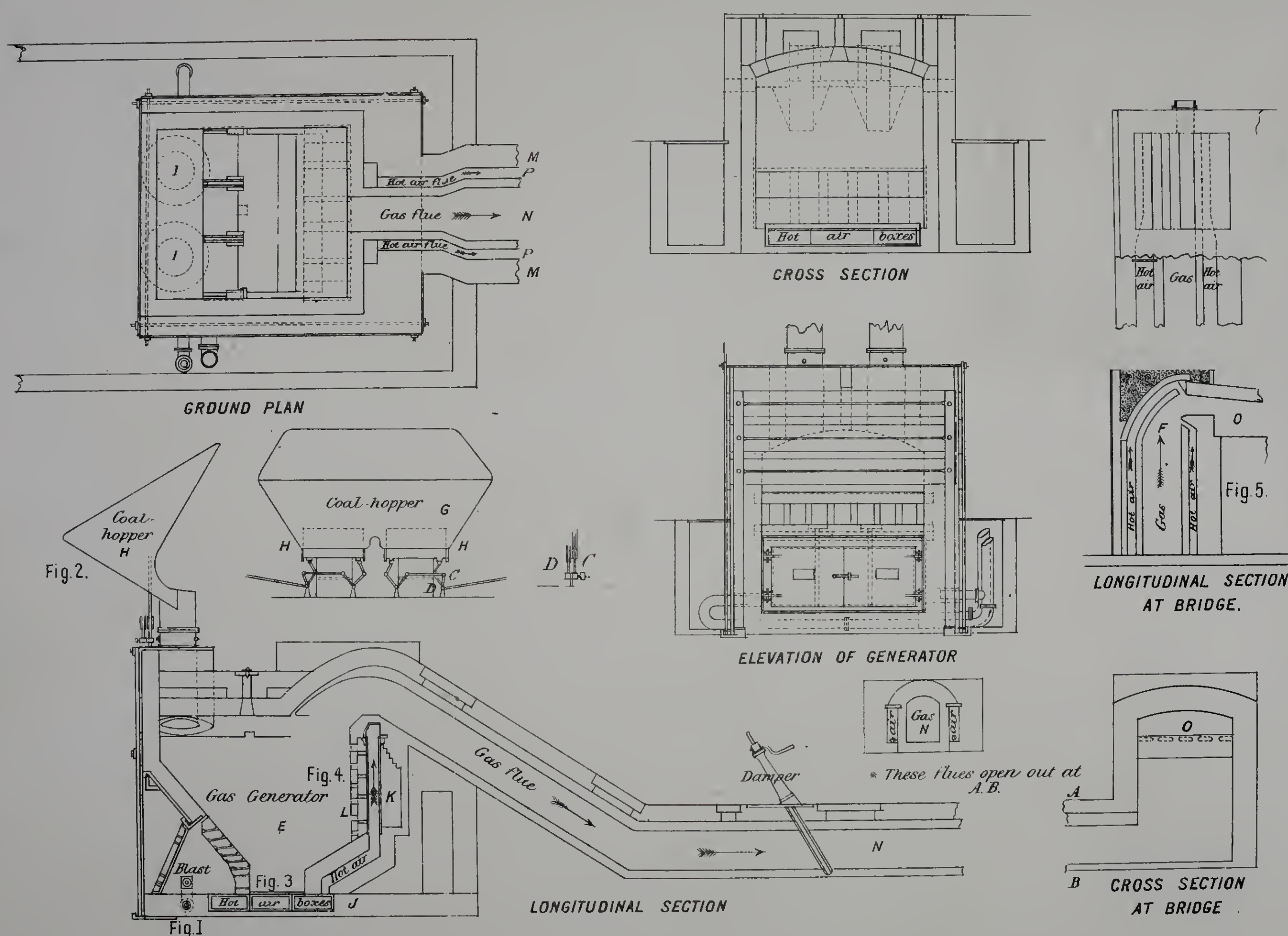
To Balance on December 31, 1882—		
Invested	£1,999 2 9	
In the Bank	355 8 1	
		£2,354 10 10
,, Entrance Fees	254 2 0	
,, Subscriptions	2,366 14 0	
,, Journals, &c., sold	195 3 8	
,, Interest	115 1 11	
,, President, B. Samuelson, Esq., M.P. (being a fee to which he was entitled as an Arbitrator, and which he directed to be paid to this Institute)	21 0 0	
,, Balance due to Treasurer	115 0 3	
		3,067 1 10
		£5,421 12 8

EXPENDITURE.

By Salaries of Secretary and Clerks	£694 0 0	
,, Office Rent, Cleaning, &c.	319 1 4	
,, Office Furniture	60 5 2	
,, Translations	50 0 0	
,, Expenses in connection with Annual Meeting in London, May 1883	40 6 0	
,, Expenses in connection with Meeting at Middlesbrough, September 1883	121 3 6	
,, Journal Publishing Expenses	691 10 6	
,, Printing, Advertising, and Stationery	295 8 0	
,, Insurance	1 2 6	
,, Postages, Receipts, &c., per Treasurer and Secretary	90 2 4	
,, Sundry Payments	44 15 3	
,, Special Bessemer Medal	15 5 0	
		£2,422 19 7
,, Investments—		
In £733 North-Eastern, Darlington, 5½ per cent. Stock, at a cost of	£999 12 6	
In £1546 Seinde, Punjaub, and Delhi 5 per cent. Stock, at a cost of	1999 0 7	
		2,998 13 1
		£5,421 12 8

DAVID DALE,
Hon. Treasurer.

TO ILLUSTRATE MR. R. SMITH-CASSON'S PAPER.

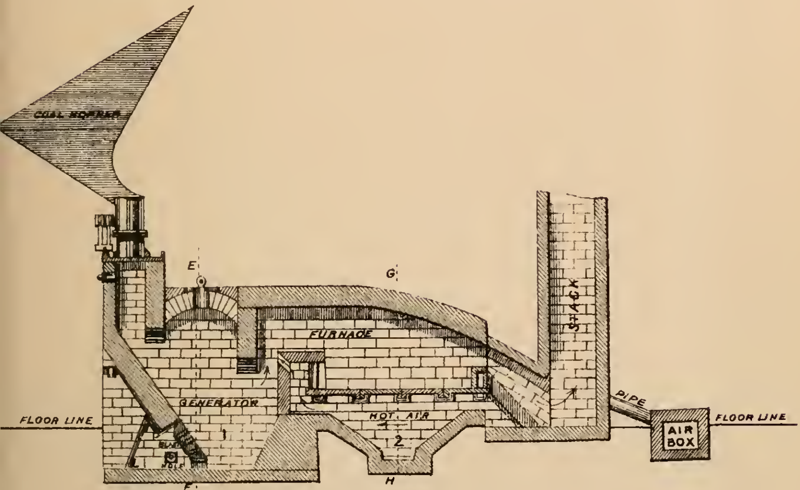


CASSON'S PATENT DIRECT ACTING GAS SYSTEM AS APPLIED TO HEATING FURNACES.

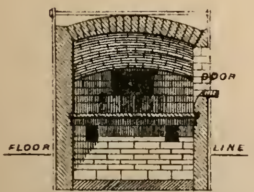
SCALE 1/8 INCH = 1 FOOT.

Ballantyne, Hanson & Co. Edinburgh & London.

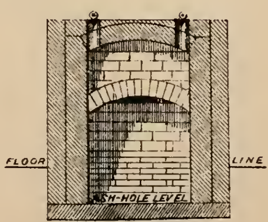
O ILLUSTRATE MR. R. SMITH-CASSON'S PAPER.



LONGITUDINAL SECTION



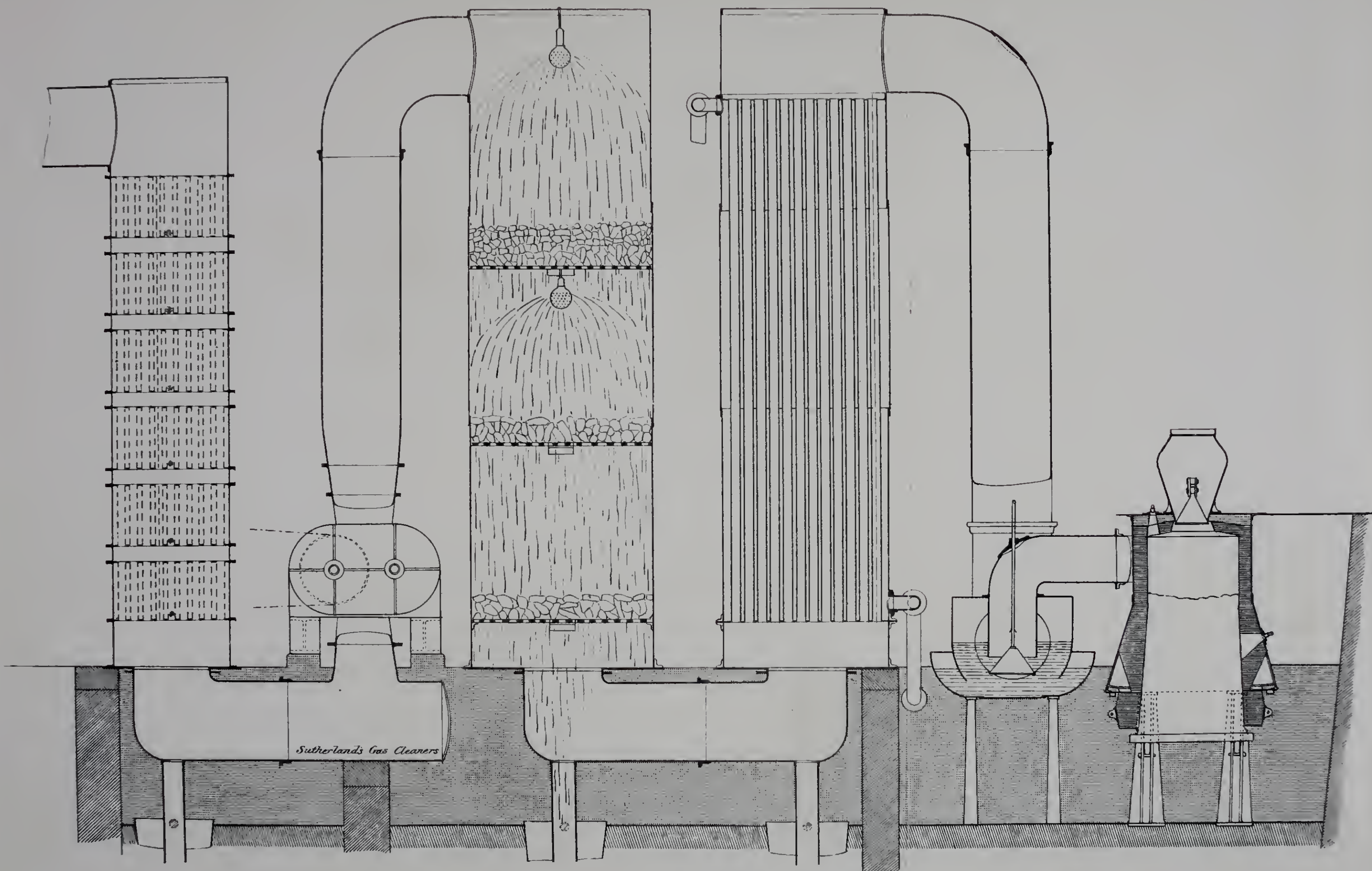
CROSS SECTION AT G.H. WITH FLUE BRIDGE



CROSS SECTION AT E.F.

CASSON'S PATENT DIRECT-ACTING GAS SYSTEM AS APPLIED TO A PUDDLING FURNACE.

TO ILLUSTRATE MR. SUTHERLAND'S PAPER.



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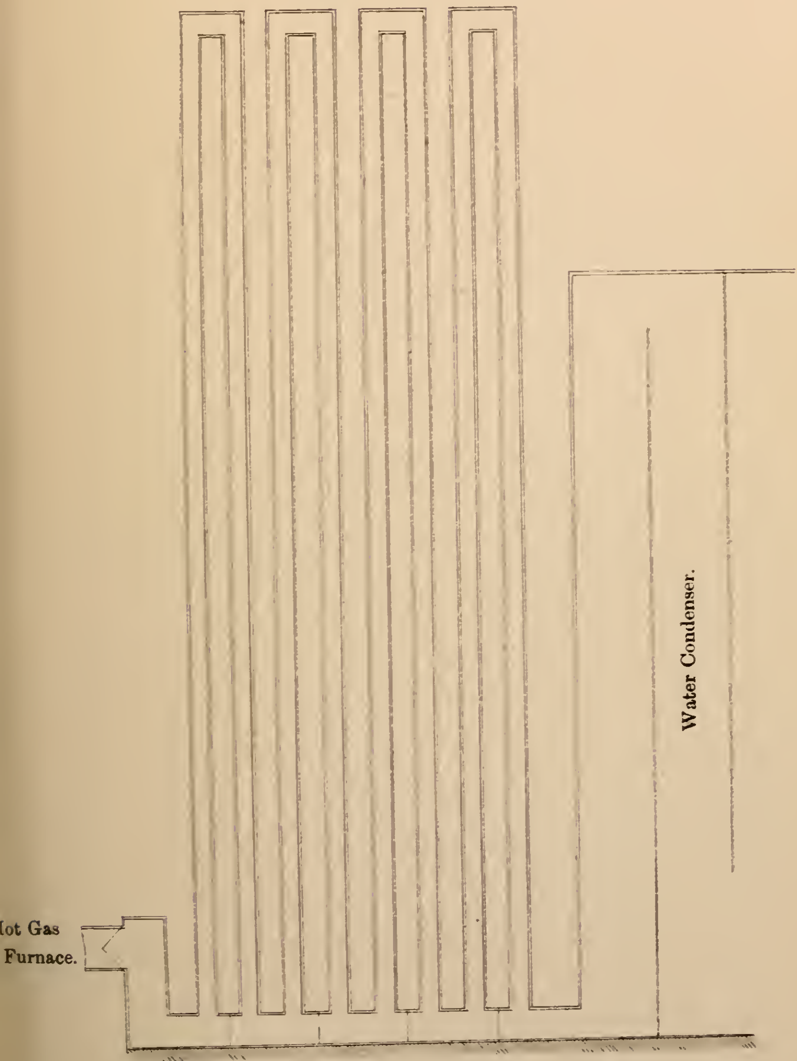
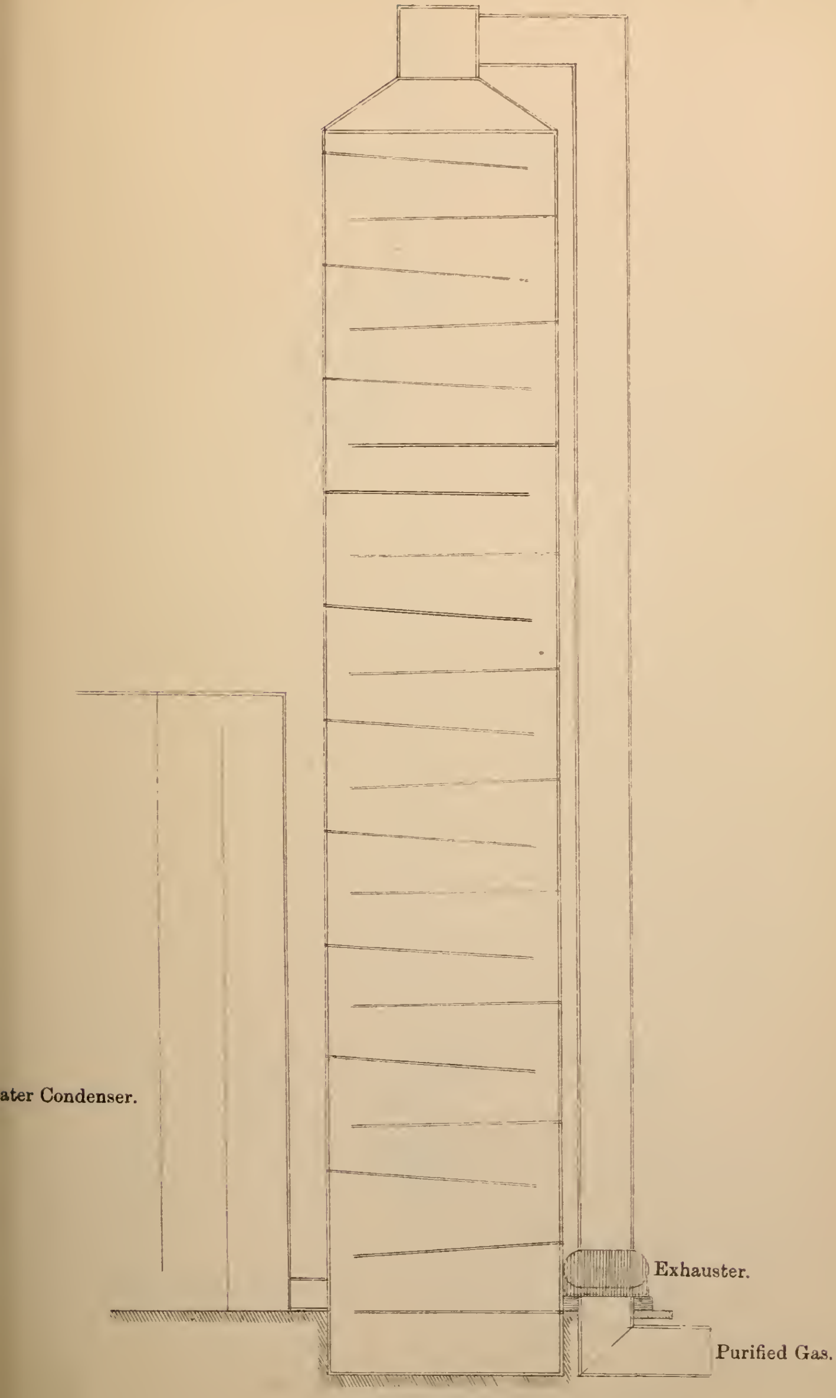
TO ILLUSTRATE MR. SUTHERLAND'S PAPER.



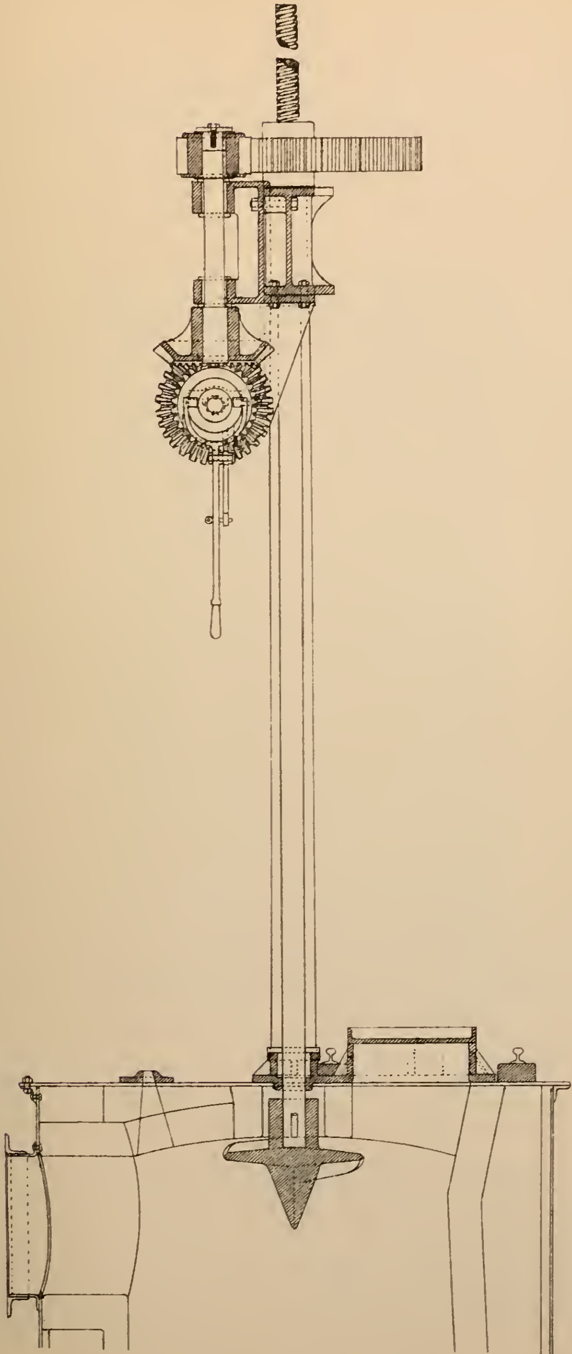
AIR COOLER.

TO ILLUSTRATE MR. SUTHERLAND'S PAPER.



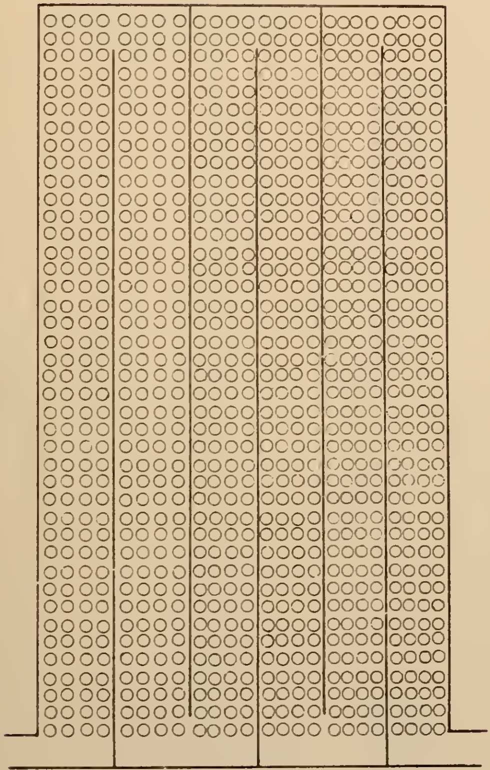
SCRUBBER.

TO ILLUSTRATE MR. SUTHERLAND'S PAPER.

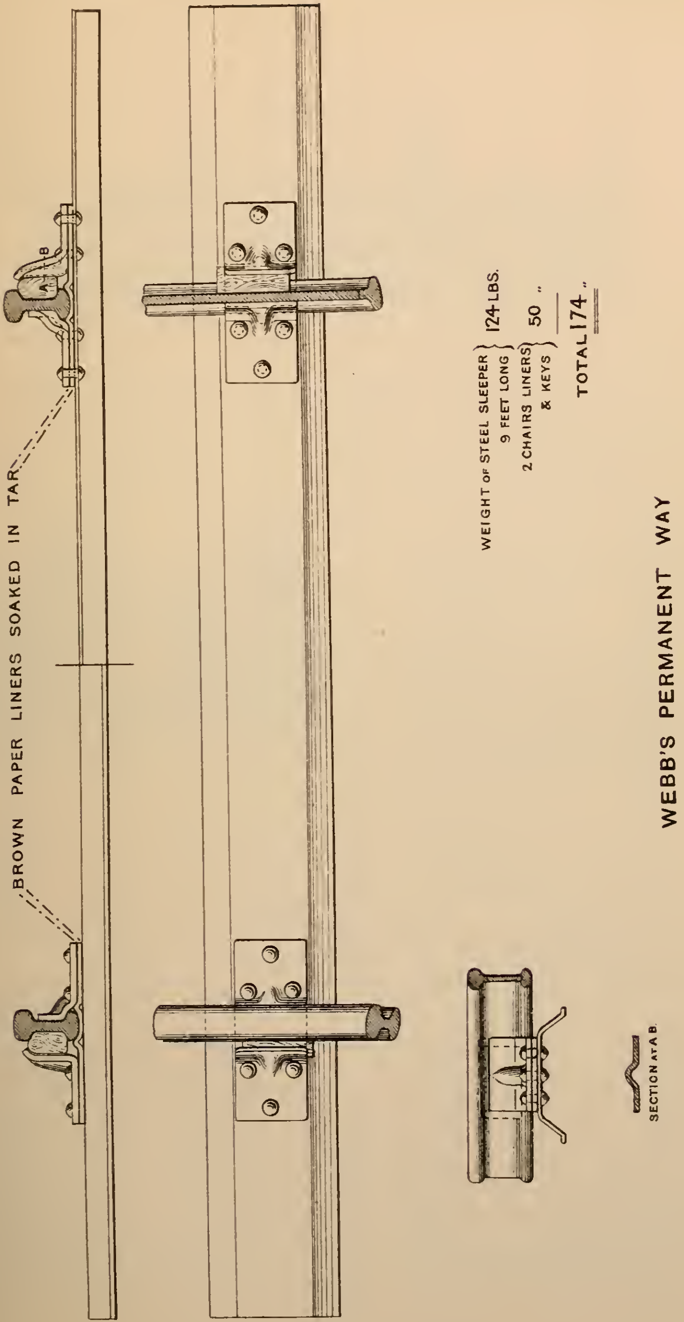


Ballantyne, Hanson & Co. Edinburgh & London.

TO ILLUSTRATE MR. SUTHERLAND'S PAPER.



Sketch shewing Tubes
in
Water Condenser.



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TO ILLUSTRATE CAPTAIN ORDE-BROWNE'S PAPER.

FIG 1.

HORIZONTAL SECTION

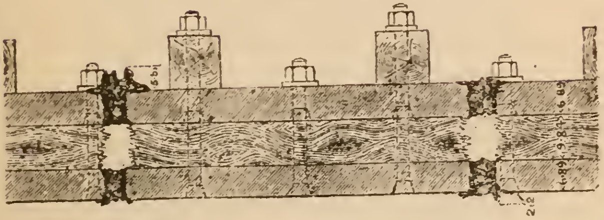


FIG 2

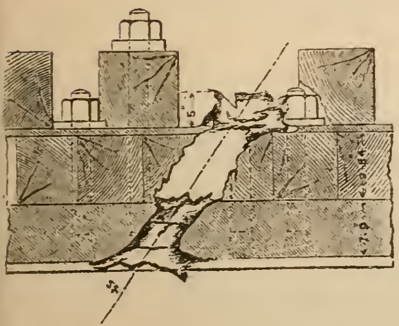


FIG 3

ROUND No 1.

FIRST ROUND AT CAMMELLS PLATE

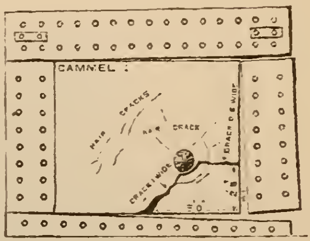


FIG. 4.

ROUND No 3.

FIRST ROUND AT BROWNS TARGET

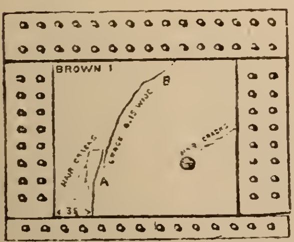
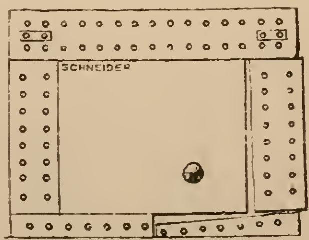


FIG. 5.

ROUND No 2.

FIRST ROUND AT SCHNEIDERS PLATE



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TO ILLUSTRATE CAPTAIN ORDE-BROWNE'S PAPER.

FIG 6.

6TH ROUND–2ND ROUND AT CAMMELL'S PLATE

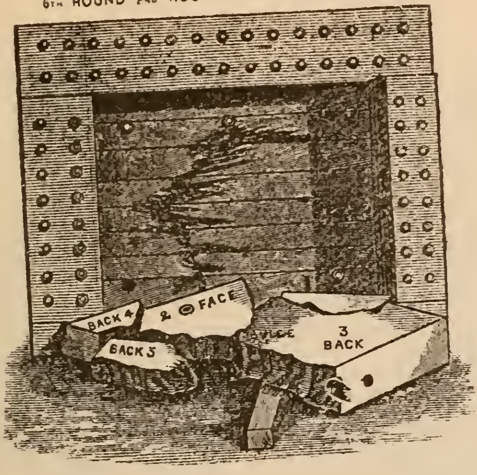


FIG 7.

5TH ROUND 2ND ROUND AT BROWN'S PLATE.

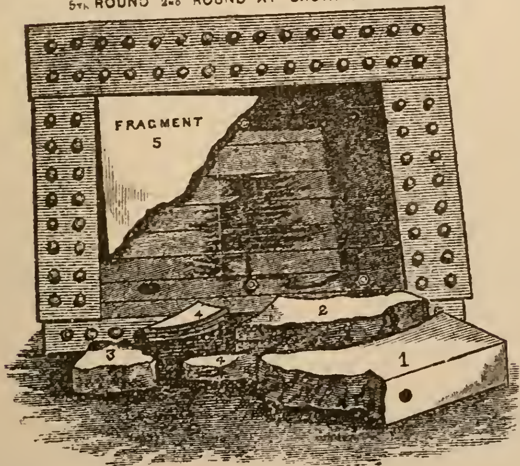
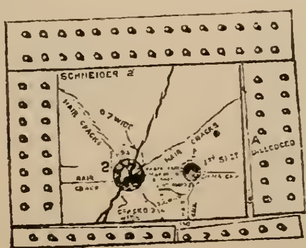


FIG 8.

ROUND 4.

SECOND ROUND AT SCHNEIDER'S PLATE.



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TO ILLUSTRATE CAPTAIN ORDE-BROWNE'S PAPER

FIG 9.

7TH ROUND 3RD ROUND AT SCHNEIDER'S PLATE

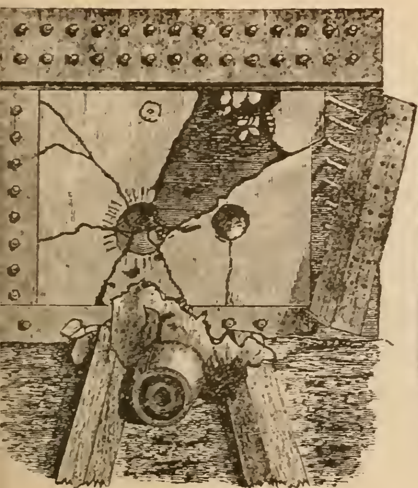


FIG 10.

8TH ROUND SCHNEIDER'S 4TH ROUND AT PLATE

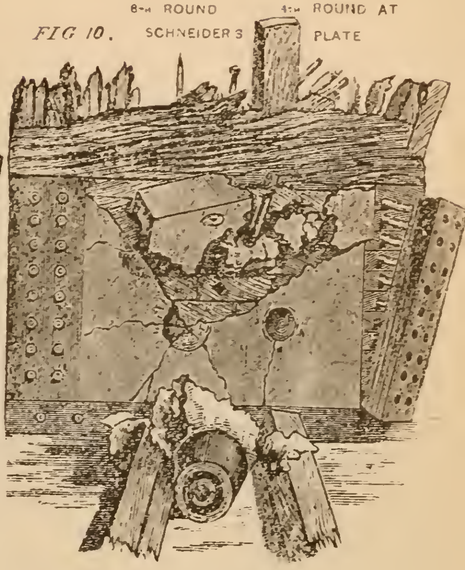


FIG 11.

PIECES OF BROWN'S PLATE ASSEMBLED

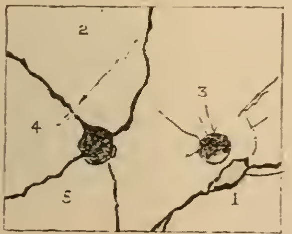


FIG 12.

PIECES OF CAMMELL'S PLATE ASSEMBLED

THE BACK AND FRONT OF THE FRAGMENT DIFFER A LITTLE IN SHAPE HERE

FIG. 13.

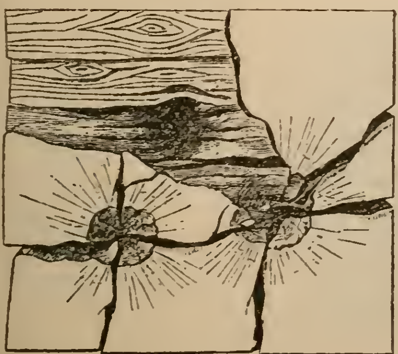
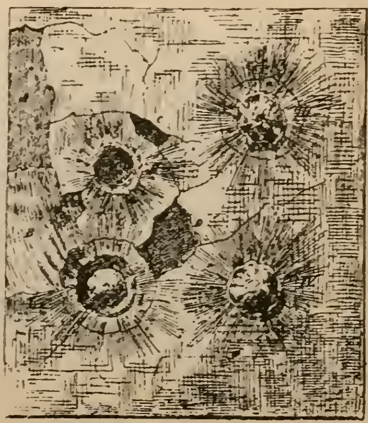


FIG. 14



TO ILLUSTRATE CAPTAIN ORDE-BROWNE'S PAPER.

FIG 15.

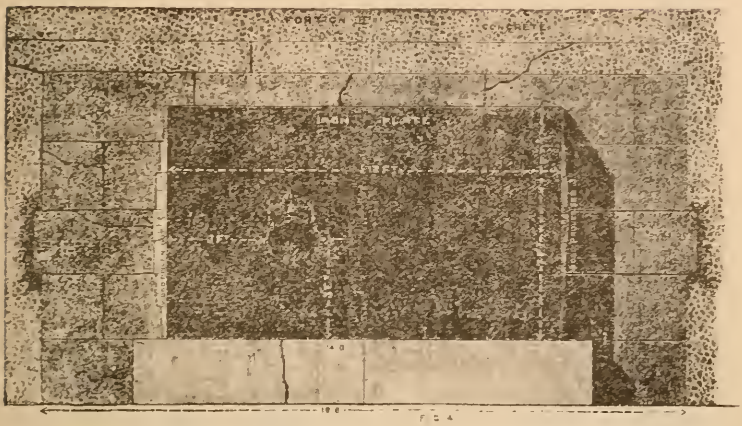


FIG 16.

STEEL FACE
CAMMELL'S (WILSONS) COMPOUND PLATE
FRONT VIEW REMOVED FROM PORTION II

FIG 17.

IRON BACK
CAMMELLS (WILSONS) COMPOUND PLATE
BACK VIEW

FIG 18.

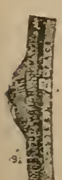
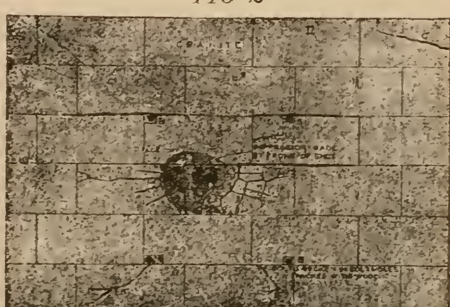


FIG 19



SHOWING PORTION II AFTER REMOVAL OF FRONT COMPOUND PLATE

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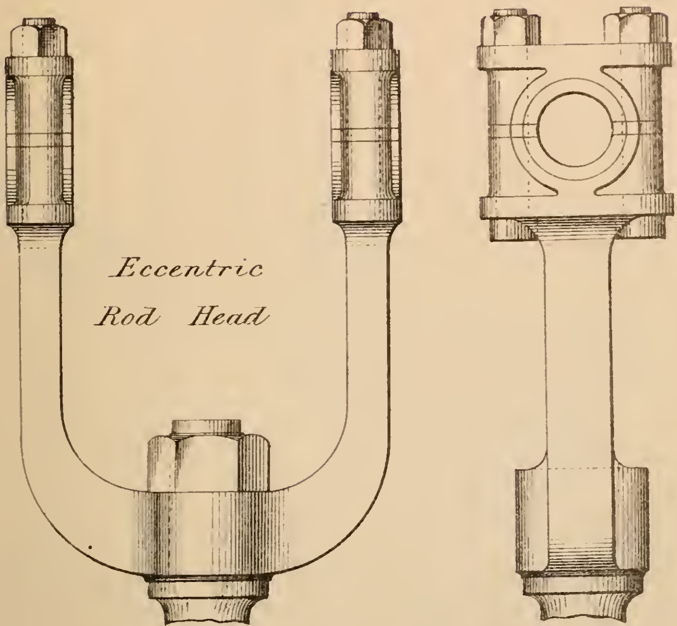
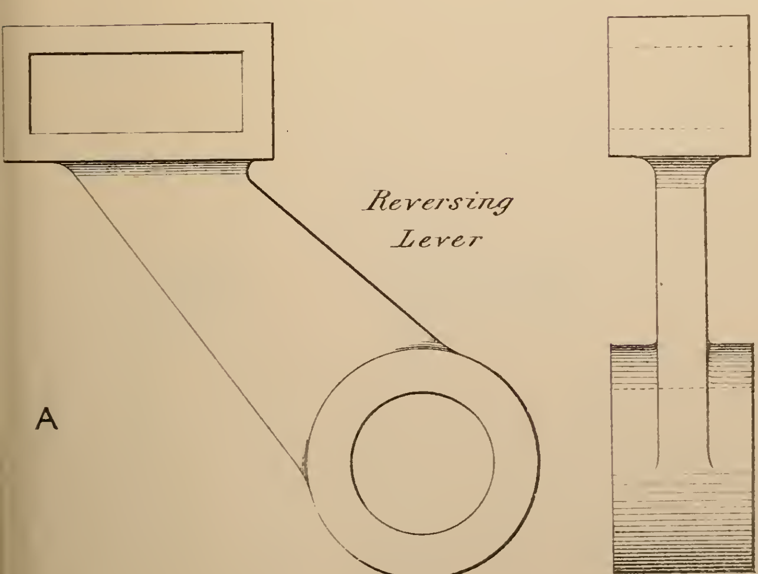
TO ILLUSTRATE MR. W. JOHN'S PAPER.





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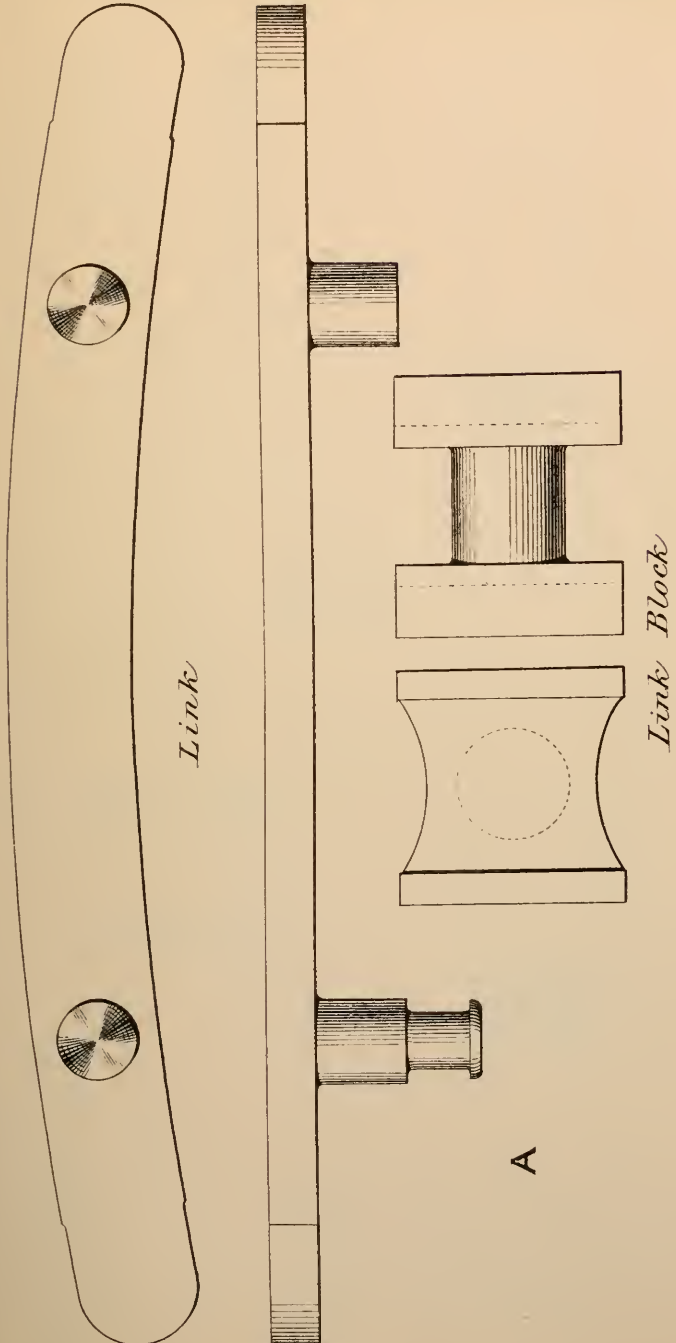
TO ILLUSTRATE MR. W. JOHN'S PAPER.



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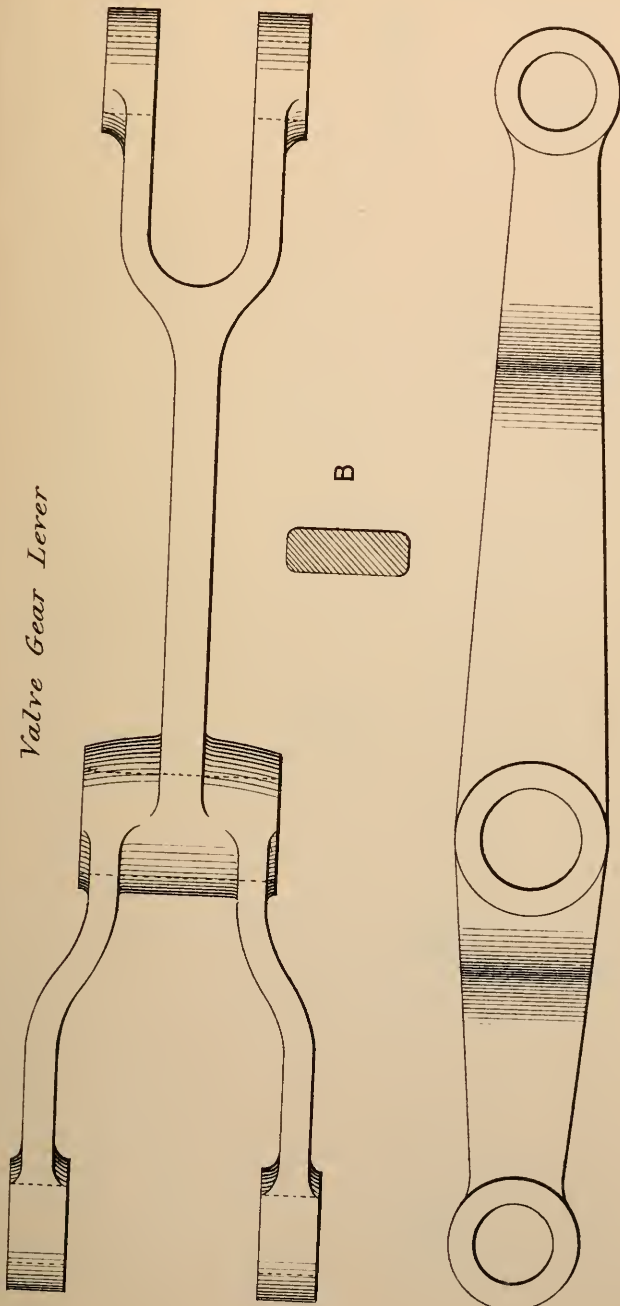
TO ILLUSTRATE MR. W. JOHN'S PAPER.



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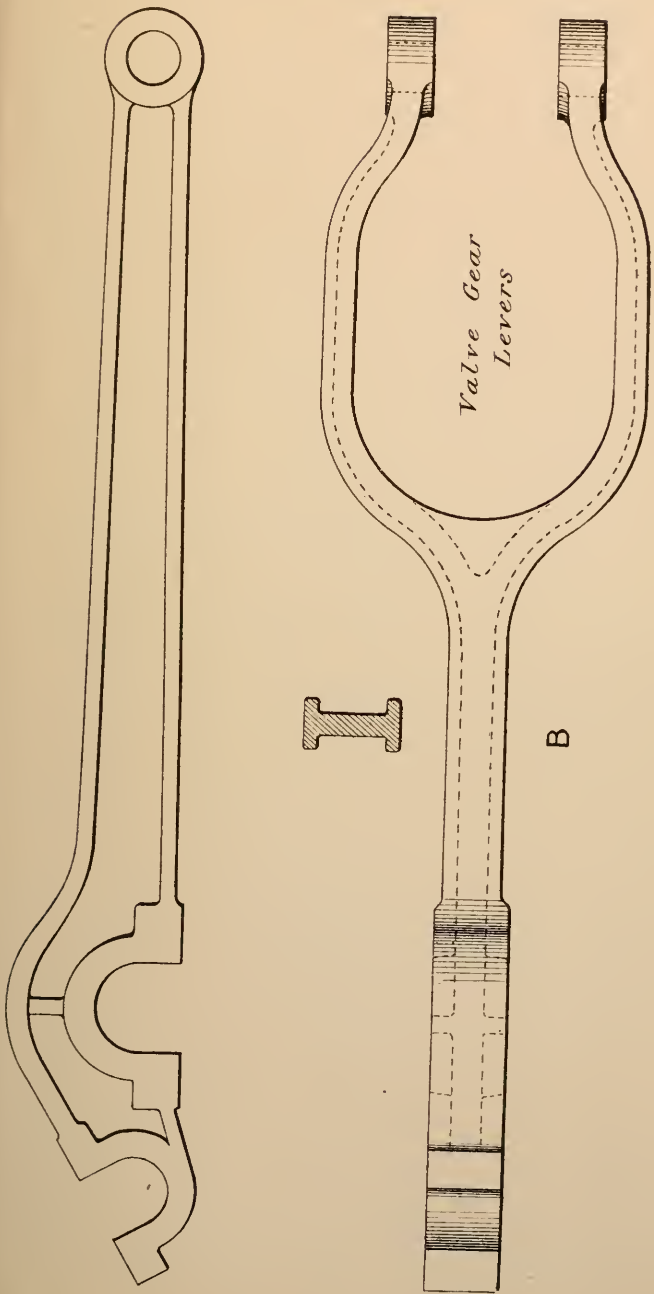
TO ILLUSTRATE MR. W. JOHN'S PAPER.



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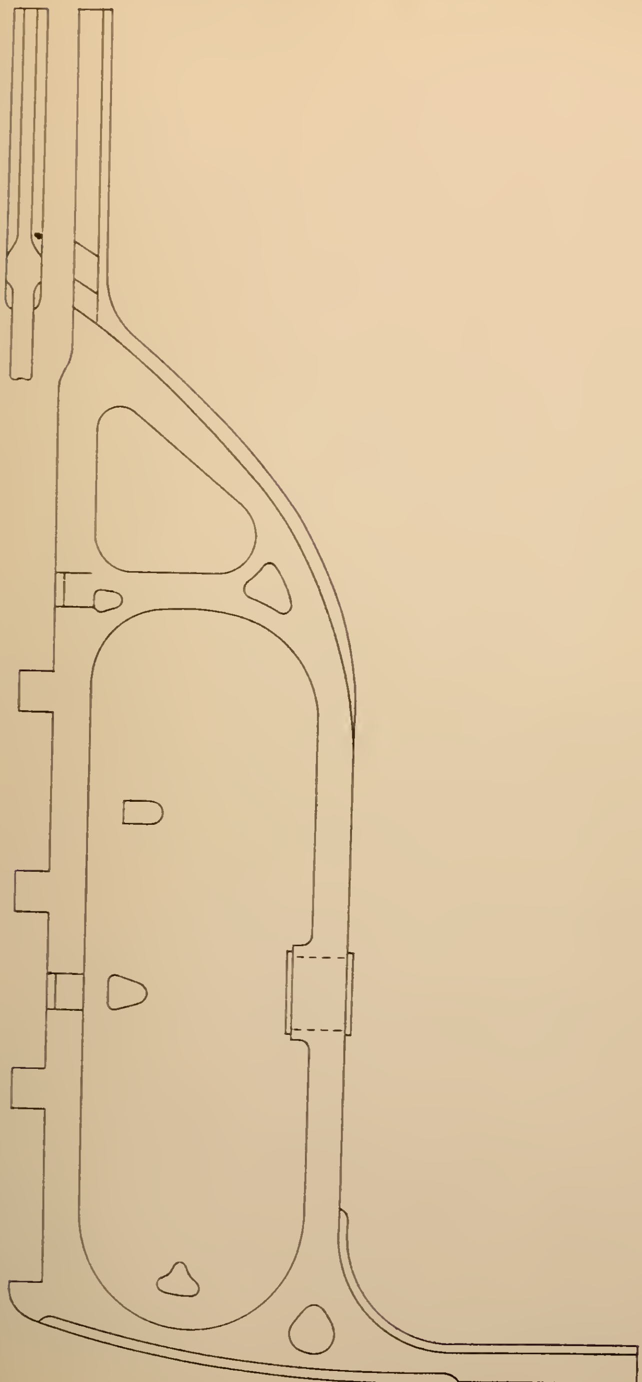
TO ILLUSTRATE MR. W. JOHN'S PAPER. PLATE XVII.



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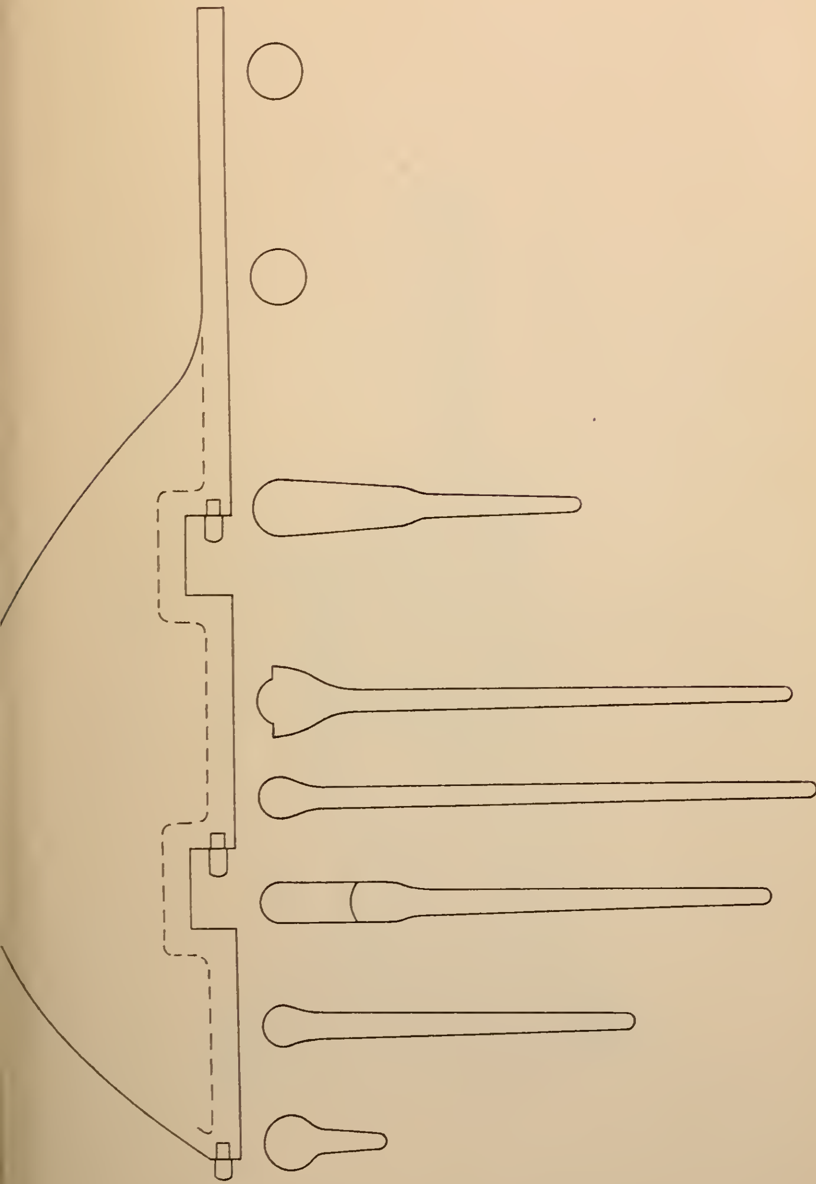
TO ILLUSTRATE MR. W. JOHN'S PAPER.



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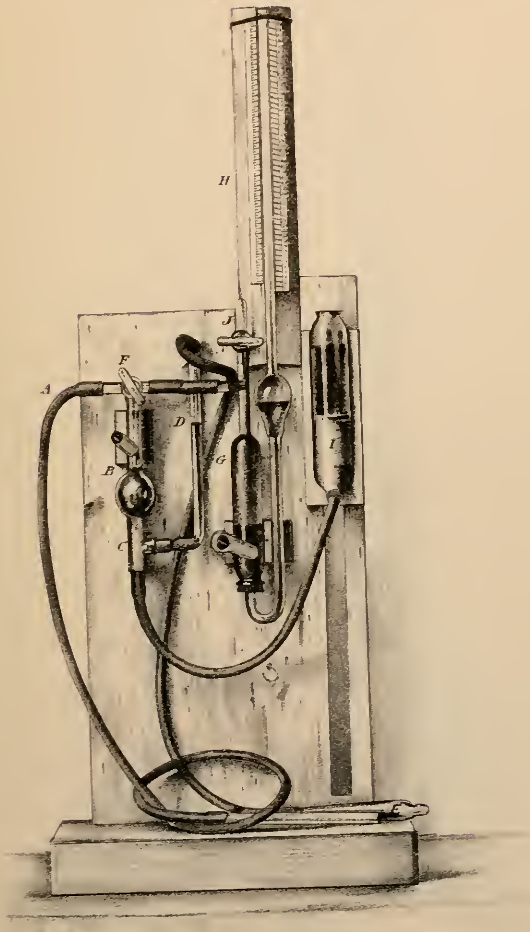
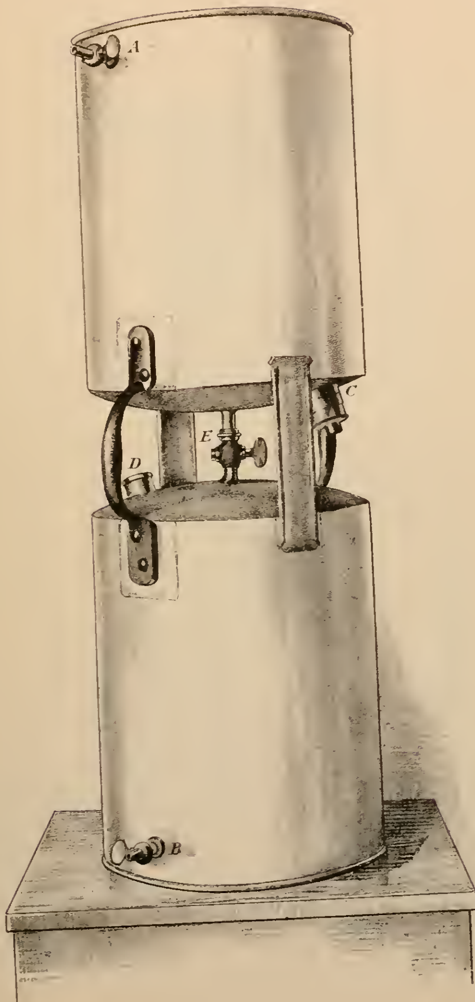
TO ILLUSTRATE MR. J. E. STEAD'S PAPER.



APPARATUS FOR TESTING WASTE GASES.

Ballantyne, Hanson & Co. Edinburgh & London.

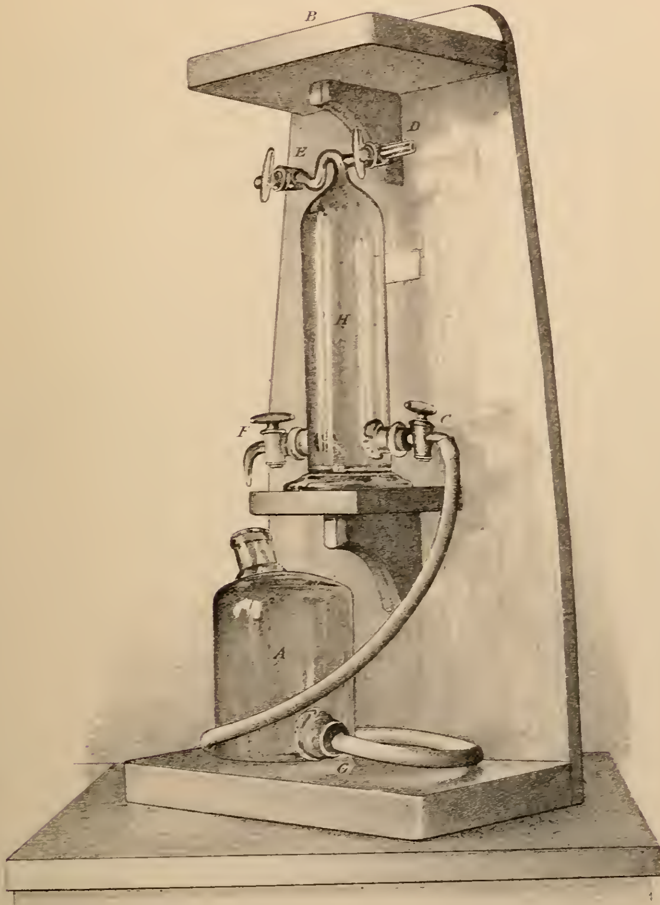
TO ILLUSTRATE MR. J. E. STEAD'S PAPER.



ASPIRATOR FOR DRAWING OFF GASES.

Ballantyne, Hanson & C° Edinburgh & London.

TO ILLUSTRATE MR. J. E. STEAD'S PAPER.



GAS SAMPLER.

Ballantyne, Hanson & Co. Edinburgh & London.

NOTES

ON THE PROGRESS OF THE

HOME AND FOREIGN

IRON AND STEEL INDUSTRIES.

I.—1884.

CONTENTS.

UNITED KINGDOM.

CONTENTS.

I.—*ORES AND FUEL.*

The Warwickshire Coalfield.—E. F. Melly in his paper* on this coalfield states that, next to the Forest of Dean, it is the smallest in England. It extends only from Coventry to Tamworth, a distance of about eighteen miles; the average width of proved workable coal being about four miles. During the year 1882 there were sixteen collieries in Warwickshire, 1,066,741 tons of coal were raised, and 4000 persons were employed; 1007 at surface, and 2993 underground. The seams lie at a considerable inclination, dipping due west. The coal-field is singularly free from faults, except the large one which practically forms its boundary. It is also very free from gas, but there is a large quantity of water which has to be dealt with by every colliery in the district. The principal distinctive feature of these coal seams is that they are all very liable to spontaneous combustion.

The Harrison Coal-Mining Machine.—Three of these machines are now in use in the Whinhall Colliery, near Alloa. The machine in question is an American invention, and is the smallest and lightest mechanical coal-cutter that has yet been brought into practical use.† It measures only 24 inches in height to the top of the throttle, and 19 inches wide over all, while its length, from the rear of the guiding handles to the point of the cutting tool, ranges from 5 feet 6 inches to 7 feet. It cuts under the coal an open channel of any desired vertical height, from 8 inches to 12 inches in front, and tapering to 2 inches

* Read before the North of England Institute of Mining Engineers.

† *Iron*, vol. xxiii. p. 187; *Engineering*, vol. xxxviii. p. 11.

in the rear; and the undercut made may vary, according to the length of the tool used, from 3 feet to 6 feet inwards from the face. The machine is actuated by compressed air, and includes a piston rod and head, made in one piece, which constitutes the projectile of the machine. The total weight of this projectile is 60 to 90 lbs., according to the length of the rod, and it strikes 190 to 210 blows per minute. One skilled man can work the machine, and all the assistance he requires is that of an ordinary labourer who shovels away the cuttings as they collect. At the Whinhall Pit, the machine is driven from the surface by means of a Norwalk 10-inch air compressor. The mean distance of the machines from the compressor is from 2500 feet to 2700 feet; the air being delivered at a pressure of from 65 lbs. to 70 lbs. per square inch. The capacity of the machine in coal-getting is equal to that of eight of the best workers with the hand-pick.

Mechanical Coal-Getter.—The Haswell mechanical coal-getter is a combination of the lever, the wedge, and the screw.* It consists of two expanding blocks, which are forced asunder by a wedge-piece, actuated in its forward motion by means of a screw-and-link arrangement. The apparatus is inserted in a bore hole in the coal, after a space has been made at the top or bottom of the seam, and the coal is spragged. The screw is then gently turned, and the sprags knocked away, and the coal comes down in a mass. The bursting action is accomplished by the wedge; the power being greatly multiplied, gradually applied, and readily governed by a judicious combination of mechanical forces. The machine is the invention of Mr. W. Low, and has been introduced at the Haswell Colliery by Mr. W. F. Hall, with great success.

New Safety Catch for Colliery Winding Cages.—A model of a new patent safety catch was exhibited at the meeting of the Manchester Geological Society, held on April 1st. The cage is one of ordinary construction, with a pair of wheels, slightly eccentric, on each side of the conductor. In winding, the wheels are held by the chains with their longest radius away from the conductors. As soon as the chains holding the weight of the cage go slack, the wheels are brought together by means of a spring, or by making the longest radius heavier, so that it falls of its own weight. The conductor, being between, is firmly gripped by the wheels. This arrangement has proved successful in a mine shaft, and is readily adapted to any

* *Iron*, vol. xxiii. p. 222.

cage. It possesses the advantages that it is always in action, and that there is no complicated machinery to get out of order.

Long Wire Rope.—Messrs. G. Elliot & Co. have completed what they claim is the largest and longest wire rope in the United Kingdom. The rope is 4½ inches wide by ¾ inch thick, and weighs about 8½ tons. The whole is composed of eight round ropes sewn together, and it will bear a strain of 140 tons. The rope, which is made for Ashton Moss Colliery, Lancashire, is 1040 yards long.

The Destructive Distillation of Coal.—In a paper read before the Institute of Civil Engineers on April 1st, W. Forster gives the results of a series of experiments on this subject. Six varieties of coal were investigated, and the results showed that the amount of sulphur remaining in the coke was always less than that originally present in the coal, and sometimes considerably so. His experiments showed that 55 to 60 per cent. of the nitrogen in the coal remained in the coke. The author's method of experiment did not account for a considerable proportion of the remainder of the nitrogen; he believed it, however, to exist partly in the tar in the form of alkaloidal substances, but principally as free nitrogen in the coal-gas. The author further showed that by the action of steam at a high temperature it is possible, by converting 40 per cent. of the coke into gas, to obtain more than 60 per cent. of the total nitrogen contained in the form of ammonia, which is equivalent to about 4 tons of ammonium sulphate for every 100 tons of coke treated.

Economic Value of Coals and Coke.—The results of comparative tests of three English coals and of coke made at Bordeaux were as follows:*—

	s.	d.	
Liverpool coal, cost at the works	21	0	per ton.
Newcastle coal, ,, ...	23	4½	,,
Cardiff coal, ,, ...	24	2	,,
Coke, with 6 per cent. moisture	22	7	,,

They were burned under an ordinary elephant boiler, and the tests lasted five days of ten hours each. The following are the respective weights of water evaporated per lb. of fuel, as from the temperature 32° F., under five atmospheres pressure; together with the respective values in money, calculated in the ratio of the evaporative efficiencies, taking Cardiff coal at 24s. 2d. per ton.

* *Proceedings of the Institute of Civil Engineers*, vol. lxxvi. p. 457.

	Water per lb. of Fuel.	Relative Economic Values per Ton.	
	lbs.	s.	d.
Cardiff	7·816	24	2
Newcastle	5·507	17	3
Liverpool	5·332	16	5¼
Coke	5·324	16	5

The Cardiff coal, though the most expensive, is the most economical.

Gaseous Fuel at the Carron Ironworks.—At the meeting of the Mining Institute of Scotland on April 13th, Mr. D. Cowan described the arrangements in course of completion for the application and distribution of gaseous fuel at the Carron Ironworks.

The waste gases for the blast furnaces are collected in the usual way, by covering their tops and leading the gases through downcomer pipes into a horizontal main, from which branches are led to the blast furnace, air-heating stoves, and steam boilers. The total length of gas mains is about 2700 ft. The whole works, which embrace an area of 25 acres, and include blast furnaces, low or light foundry, high or heavy foundry, and brickworks, are being so arranged that no coal will be used except in the blast furnaces. A nest of gas-producers is provided in case there should, at any time, be an insufficiency of gas.

New Form of Pyrometer.—In a paper read before the Chemical Society,* T. Carnelley and T. Burton describe a new form of pyrometer, which, though it has several drawbacks, overcomes, for many purposes, most of the difficulties attaching to the older pyrometers. Being exceedingly simple in its construction and arrangement, it is cheap, and does not readily get out of order. When once placed in position, it requires little or no manipulation except the reading off of two thermometers and a reference to a table.

The principle of the method is as follows :—If a current of water of known temperature be allowed to flow at a constant rate through a coiled metallic tube placed in the space the temperature of which is to be ascertained, the increase in the temperature of the outflowing water will be the greater the higher the temperature of the space. The authors do not claim for the pyrometer a scientific degree of accuracy, but believe that it will be of great value in manufacturing operations, where a measurement of high temperatures is required, and where an error of a few degrees is of little consequence. When the authors had almost completed their work, they found that the principle of the pyrometer recently devised by Messrs. Boulier Bros. is exactly identical with

* *Journal of the Chemical Society*, 1884, pp. 237–241.

their own. With regard to priority, they state that their pyrometer, both in principle and in form, was invented so long ago as 1879, but pressure of other engagements prevented it being thoroughly tested until quite recently.

Gauntlett's Pyrometer.—The pyrometer of Mr. W. H. Gauntlett of Middlesbrough, is based upon the principle of the difference of the rates of expansion in different substances.* For temperatures up to 1500° the instrument is made partly of iron and partly of fire-clay. For temperatures up to 1000° it is made partly of iron and partly of brass. In both cases the difference between the expansion of rods made out of the two materials is caused to act by a system of springs upon a needle revolving upon a dial. This pyrometer is much used for blast furnaces, steam boilers, and other purposes, and it appears to be at once durable, trustworthy, and sensitive.

II.—*BLAST FURNACE PRACTICE.*

Scotch Pig Iron.—In a letter addressed to the *Mechanical World*,† D. Cowan, manager for the Carron Company, states that, with a view to compare the pig iron manufactured by his company with that manufactured elsewhere, he purchased in the open market several small parcels of No. 1 grade of some different high-class brands, in which it is understood no cinder is being introduced, and caused them to be subjected to chemical analysis and to mechanical tests, with the following results:—

Constituents.	I.	II.	III.	IV.	V.	Carron Pig Iron.
Iron	92·62	90·26	92·26	91·60	90·70	92·12
Combined carbon	0·71	0·60	0·45	0·82	0·85	0·90
Graphite	2·97	3·27	3·12	2·44	2·69	2·88
Silicon	1·06	3·39	2·15	1·61	2·83	1·76
Manganese	1·87	1·77	1·30	2·58	2·13	1·58
Phosphorus	0·50	0·44	0·44	0·69	0·54	0·47
Sulphur	0·03	0·04	0·04	0·03	0·04	0·04
Totals	99·76	99·77	99·76	99·77	99·78	99·75
Total carbon	3·68	3·87	3·57	3·26	3·54	3·78

* *Iron and Coal Trades Review*, vol. xxviii. p. 694.
† Vol. xvi. p. 222.

The average of ten tests for each sample gave as follows :—

	Tensile Strength Tons per sq. inch.	Crushing Strength. Tons per sq. inch.	Bending Stress in lbs.	Specific Gravity.
No. I.	10·84	56·23	724	7·1165
,, II.	13·06	59·67	792	7·0815
,, III.	13·15	51·01	800	7·1146
,, IV.	12·39	61·63	776	7·1367
,, V.	11·07	55·52	668	7·0679
Carron pig	12·46	56·56	793	7·0895

	Ultimate Elongation on 10 in.	Ultimate Depression on 2 in.	Ultimate Deflection.
		Per cent.	Inch.
No. I.	0·61	7·03	0·29
,, II.	0·65	12·61	0·27
,, III.	0·77	11·90	0·32
,, IV.	0·61	6·54	0·28
,, V.	0·64	7·92	0·28
Carron pig	0·75	9·70	0·32

III.—*MANUFACTURE OF IRON AND STEEL.*

Stewart's Rapid Cupola.—This cupola has three rows of tuyeres, one above the other; each tuyere in the top row being provided with a shut-off valve. The valves have their plugs connected together by a malleable iron pitch-chain, and are opened or shut simultaneously, each to an equal extent, by one handle. The three rows of tuyeres all communicate with an annular casing to which the stand-pipes for the blast are connected, and opposite each tuyere is provided a circular cover that moves off, and when down is perfectly air-tight. They are also provided with mica discs. The respective areas of the three rows of tuyeres have been proportioned by experiment to give the most effective distribution of blast with economical results. The cupola is arched over at the top, and has an opening fitted with a flap door for the escape of the waste gases. The flap door may be set at such an angle as to cause all sparks to fall at the base of the cupola. It is claimed for the cupola that it melts rapidly, with great uniformity,

with much less than the usual quantity of fuel, and is not more expensive than the ordinary cupola; that there is an absence of flame at the top; and that the waste gases are very free from carbonic oxide.

The following table shows the results of a test of this cupola made at the St. James's Foundry, Bradford:—

*Test of Stewart's Rapid Cupola.**

	Time.	Charge of Coke.	Charge of Iron.	No. 3 Roots Blower. Speed of Blower.	Pressure of Water.	Time when Taken.
	A.M.	Lbs.	Lbs.	Revolutions.	Inches.	
Time of lighting fire . .	10	Bed 336	1,792	425	37	1.10
Put in coke for bed of cupola	10.30	,, 112	2,016	430	32	1.40
Making up of door . .	11	,, 112	2,016	425	29	2.15
Commenced charging . .	11.5	,, 112	2,016			
	P.M.					
Filled up cupola . . .	12.30	,, 112	2,016			
Commenced blasting . .	1.5	,, 112	2,016	Fuel used for bed, 836 lbs.		
Metal running down . .	1.15	,, 112	2,016	Fuel used for fusion, 896 lbs.		
Took away first metal 35 minutes after blasting	1.40	,, 112	2,016	Total consumption, 1232 lbs.		
Second metal taken . .	2.15	,, 112	2,016	Amount of iron melted, 17,920		
Third ,, ,, . .	2.30					
Fourth ,, ,, . .	2.35	,, 1,232	17,920			
Finished charging . .	2.15					
Finished blasting . .	2.35					

Remarks.—This was a melting of 8 tons of iron, with 1232 lbs. of coke, in one hour and a half, from starting to finishing blasting. The time taken to melt the iron after having taken away the first ladleful of metal from receiver to taking away last metal, was only fifty-five minutes.

The charge consisted of 14·54 lbs. of iron to one lb. of coke.

The coke used, exclusive of bed, was 896 lbs., and the amount of metal melted 17,920 lbs., or one cwt. of coke per ton of iron.

External diameter of cupola, 4 feet; internal diameter of melting part, 1 foot 10 inches; length of cupola shell, 19 feet.

The Burch-Allen Continuous Puddling Furnace.—This furnace consists of three primary parts, a fire-grate, a hearth, and a rotator. The hearth, which is slightly inclined, is of considerable length, and has a rocking motion imparted to it, which causes the charges of molten metal to flow from side to side, and to pass at the same time slowly onwards towards the rotator. This latter appliance is lined with suitable refractory material, and contains an inverted helix extending from end to end. It is mounted horizontally on rollers.

* *Iron*, vol. xxiii. p. 497; *Engineering*, vol. xxxvii. p. 56.

Molten metal is charged on to the hearth, in quantities of about 1 cwt. at a time, from a fixed receptacle placed on one side of it, a charge being made every time the hearth rocks towards the feeder. The metal is brought to nature in the rotator, where it is also balled, the balls falling out in succession and being caught upon small carriages which take them to the shingling hammers.

When iron of a steely character is required the charges do not pass into the rotator, but are run into moulds from the lower end of the hearth, the necessary quantity of spiegel being added to the metal on the hearth shortly before tapping, so as to ensure a thorough incorporation.*

A modification of the process consists in replacing the long rocking chamber by a series of smaller chambers acting in concert.

The Preservation of Iron.—In a report of the Austrian Consul-General at Liverpool concerning a method of preserving iron from rust,† he states that the metal is first subjected to the action of hydrochloric acid, which dissolves the surface of the iron and leaves it covered by a very thin and firmly adhering layer of graphite. It is next freed from ferric chloride by the action of water or steam, then dried, and afterwards washed with a solution of india-rubber or gutta-percha in petroleum, which is allowed to dry slowly, and the iron then appears covered with a solid enamel-like coating. Instead of being enamelled in this manner, the iron may be dipped into a bath of silicate, boric anhydride, soda, and lime, and a very pure and shining silicate of iron fills up all the pores of the metal.

Smooth Castings.—A saving of about 80 per cent. is made by substituting for the coal-dust and charcoal used with sand a careful mixture of one part of tar with twenty parts of sand. Castings produced from moulds made with such a mixture are smooth and bright, because the tar prevents the metal from adhering to the sand and also prevents the formation of blisters. Such a mixture also aids considerably in the production of large castings, as the tar, it is stated, absorbs the humidity of the sand.

Cyfarthfa Steelworks.—These new works have just been completed by Edward Williams of Middlesbrough.‡ The old ironworks

* *The Mechanical World*, vol. xvi. pp. 185 and 329.

† *Archiv für Gesetzgebung und Statistik*, vol. xxxvi. p. 245.

‡ *Iron*, vol. xxiii. pp. 499 and 521.

have been completely dismantled, and a colliery is being opened up to supply the new works with the necessary fuel. Three blast furnaces have been erected, and the foundation of a fourth has been laid. There are three vertical engines for supplying the blast, and these have air cylinders 72 inches in diameter, and steam cylinders 33 inches in diameter, working twenty-five to thirty strokes per minute, and giving a pressure of blast of 5 to 6 lbs. per square inch. The steam for these engines is produced by nine Galloway steam-boilers, which raise steam to a pressure of 80 lbs. per square inch. The boilers are fitted with Green's economisers. Seven Cowper's hot-blast stoves have been erected, and the blast will be heated to 1400° F. A gantry, 300 feet long and 35 feet wide, runs the whole length of the furnaces and parallel with them. The materials are unloaded into about twenty bunkers, each of which is capable of holding 1000 tons. The site for the gantry and bunkers is formed by the tops of the old blast furnaces.

There are two 8-ton converters, which, however, are capable of working 10 tons each. The blowing-engines for the converters are vertical compound condensing engines with high-pressure cylinder 42 inches in diameter, and low-pressure cylinder 78 inches in diameter. There are two air cylinders each 55 inches in diameter, and all the cylinders have a stroke of 5 feet.

The cogging-mill engine is of the reversing type with a pair of cylinders 40 inches in diameter, and will cog a bloom of from 15 inches square to 7 or 8 inches square. The rail-mill engine is of the reversing type with cylinders of 50 inches in diameter. In the rolling machinery the diameter of the cogging rolls is 36 inches, and that of the rail rolls 27 inches. The rail-finishing shed stands in front of the rail-mill, and is covered over by a corrugated iron roof.

The Staffordshire Steel Company's Works.—These works* have been recently completed, and some further particulars regarding them are given by *The Ironmonger*.† The converters are of 5 tons capacity, and are arranged in a row; they have 25-ft. centres, and are placed 15 feet above ground level. Steam is obtained from a row of ten boilers working up to a pressure of 80 lbs., and part of it is employed to drive two pairs of blowing-engines, each capable of blowing one converter at a pressure of 15 lbs. The stove used for heating the bottoms is of considerable length, and has a double track. The fire is in the

* *Journal*, 1883, p. 706. † Vol. xxxii. p. 3.

centre. By a new contrivance the bottoms reach their maximum heat by degrees, and are cooled down with equal slowness. As a consequence there is an absence of warping. The stove holds 24 bottoms, which are charged in at the one end and drawn out at the other.

A very valuable device is in use upon the Bessemer platform. This is probably unknown at other English works, and consists in a chimney back having the appearance of the boiler of a saddle-type locomotive reared on end. A double casing of boiler-plate with water circulating inside is made to replace the usual brickwork chimney back, which has frequently led to accidents to workpeople, owing to the falling off in heavy sections of the accumulated scale, and has, moreover, caused the firing of roofs. Here it is replaced by an arrangement which, while it is a source of safety, contributes most efficiently to the cooling of the platform.

The New Basic Steelworks of the Glasgow Iron Co.*—The blast furnaces are three in number, and their weekly make of pig iron is about 200 tons each. The Company possess extensive deposits of clay and blackband iron ores, and have also a stock of highly phosphoric tap and mill cinder which has been collecting for the last thirty years, and is estimated to contain from 150,000 to 200,000 tons. Sulphur is present in but small quantities and exclusively as sulphide of iron, of which compound the range is from 0·35 per cent. in mill-cinder to 0·70 per cent. in tap-cinder. The Bessemer shop is distant from the blast furnaces about 300 feet, and covers an area roofed in by four bays of 45 feet span and one of 70 feet span, and having a length of 150 feet. There are to be three 8-ton converters, one of which is, as a rule, to be held in reserve. There are two semicircular casting pits which are combined at their inner terminals, the radius of each being 25 feet. The blowing-engine for the converters will be a horizontal one having a 20-ton fly-wheel and making a speed of forty revolutions per minute. For providing steam there will be about ten boilers made of basic steel and having a working pressure of 80 lbs. per sq. inch.

Progress of the Basic Process.—The following data relating to the progress made by the basic process have been recently published.† The North-Eastern Steel Company, Middlesbrough, commenced in June 1883 with four converters, and are now fully at work

* *Engineering*, vol. xxxvi. p. 238.
† *Berggeist*, vol. xxix. p. 35.

producing rails and soft material, which latter has the composition:—Carbon, 0·12 to 0·15 per cent.; sulphur, under 0·05 per cent.; phosphorus, under 0·04 per cent.; manganese, under 0·4 per cent. Two converters were, in 1883, in use at Eston; four were built by Charles Cammell & Co. at Workington; two have been built at the Cyfarthfa Works, three at the Staffordshire Company's Steelworks, and three at the works of the Glasgow Iron and Steel Company.

[In the United States two converters were started at Scroton.

In Belgium the Société d'Athus started two new converters. Two others were started at Ougrée. The Boël Works in La Louvière with two converters is nearly completed.

In France at the Longwy Works three converters were started; two at Aire, two at Aubin, two at St. Nazaire, two at Joeuf, and two at Valenciennes; while two are nearly ready at the still unfinished Montaire Works.

In Germany, at Rothe Erde near Dortmund, three 10-ton converters have been started; the Ilsede Works has had three converters in use since the end of 1882; the Phœnix Works have two converters nearly ready. Three converters are being built at Dudelingen in Luxemburg, and two are about to be built by the Hoesch Iron and Steel Works at Dortmund. On the Saar and Moselle four works have been licensed to use the basic process; these have not yet started the process, the only two works in the district which use it being the steelworks of De Wendel & Co. at Hayingen, and those of Stumm Bros. at Neunkirchen.]

The Davy Steel Process.*—Mr. Alfred Davy of Sheffield has invented a process which is based on the same principle as that of Bessemer, but differs from it in the way in which the blast is applied. The converter resembles an ordinary ladle used for foundry purposes, and is covered over by a lid, having a short spout projecting upwards from it at a small angle. The tuyere for the blast passes down through the cover nearly to the bottom of the converter, which is consequently independent of the blast-pipe connections, and the charges may be either large or small, as is required.

Improvement in the Manufacture of Steel.—W. Beardmore of Parkhead Forge and Steelworks, Glasgow, and J. MacCallum Cherrie of the same works, have taken out a patent for an improvement in the

* *Iron*, vol. xxiii. p. 222.

casting of steel,* which consists in employing shallow moulds having a large surface instead of the ordinary deep mould. This alteration is intended to assist the escape of gases from the steel, and to produce in consequence ingots comparatively free from blowholes.

Steel-Lined Soaking Pits.—Mr. G. J. Snelus has recently patented an improvement in the Gjers soaking pit, which, it is claimed, produces in the ingot a more uniform heat than has hitherto been obtained. It consists in providing the pits with a soft steel lining, consisting of a rough casting of Bessemer or Siemens steel. The steel conducts the surplus heat from the bottom to the top of the pit, and so tends to produce a more uniform temperature, while it does not suffer injury from contact with the ingots in anything like the same degree as brickwork.

New Method of Producing Steel Plates.—Dr. H. Muirhead, President of the Philosophical Society of Glasgow, has recently brought before that body some particulars of a method of manufacturing steel plates that is of much interest. It is the invention of Mr. J. Whitley, of Leeds, who has erected works for prosecuting the manufacture. A hollow metal cylinder, lined with ganister or other fire-brick, revolves at high speed, the axis being horizontal. A gutter passes into the interior along its whole length. In this gutter is poured molten mild steel, which, escaping through the holes, is carried round by the swiftly revolving case, and is formed into an inner cylinder of steel an inch or more in thickness. The cylinder, while still hot, is withdrawn, cut across by means of a saw, put into a rolling-mill, and rolled to the length and thickness required.

Rolling Steel Tubes and Hollow Cylinders.—An invention has recently been brought forward for the manufacture of weldless cylinders of iron or steel of comparatively large diameter by working the metal lengthwise of the cylinder, as well as circumferentially by a rolling operation. To effect the elongation of the cylinder it is mounted upon a mandrel or bar carried by a carriage, which is provided with wheels to run on guide-ways. These rails are below and at right angles to a roll carried on bearings so as to be just above the mandrel. The driving mechanism is arranged so that it can be readily turned either way. The carriage, with the cylinder upon the mandrel, is pushed forward until the cylinder is gripped between the roll and

* *The London Iron Trade Exchange*, vol. xxxv. p. 19; *Engineering*, vol. xxxvii. p. 579.

the mandrel; the roll is then revolved, and, acting upon the cylinder, draws the carriage forward until it has acted upon the entire length of that portion of the cylinder which is above the mandrel. The roll is then stopped, and a partial turn is given to the cylinder so as to bring another portion of it uppermost. The carriage is then pushed in the opposite direction until the cylinder is again gripped between the roll and the mandrel; the roll is again revolved in the opposite direction, and the same operation is repeated until the whole circumference of the cylinder has been acted upon. When the cylinder has been brought to the required length, it has its circumference extended by means of a pair of rolls in the ordinary manner. In this way the cogging of the cylinder is effected by the rolls extending it lengthwise, and the finishing by rolls extending it circumferentially. The carriage may be moved backwards and forwards and turned round by means of a hydraulic cylinder.

IV.—*PHYSICAL PROPERTIES OF IRON AND STEEL.*

Hot Blast Stove.—A regenerative hot blast stove has been patented by B. Ford of Middlesbrough and J. Moncur of Distington. The principal object of the invention is to obtain a better distribution of the flame and heating currents over the area of the regenerative part of the stove. The gas and air enter the combustion chamber through two horizontal rows of apertures, and are thus properly mixed and distributed. The interior of the chamber and its staying walls become intensely heated, and the heated currents and products of combustion pass down and through the regenerator. The latter has parallel walls and lozenge-shaped stays, and these, presenting a large extent of surface, absorb the greater part of the heat. The products of combustion pass through internal valves to a flue, and thence through another valve into the chimney.*

The Physical Condition of Iron and Steel.—In a paper on the molecular rigidity of tempered steel contributed to the Institution of Mechanical Engineers last year, Prof. D. E. Hughes advanced the theory that the molecules of soft iron were comparatively free as regards motion among themselves, while in hard iron or steel they were extremely rigid. He has since widened the field of research so as to embrace all the physical changes which occur in iron and steel,

* *Iron*, vol. xxiii. p. 178.

and has found by experiments that the following laws hold with every variety of iron and steel : * The magnetic capacity is directly proportioned to the softness or molecular freedom, and the resistance to a feeble external magnetising force is directly as the hardness or molecular rigidity. The instrument which the author has constructed and used in these experiments, and which he has named a "magnetic balance," is described in detail. Mechanical tests and chemical analyses have failed to find any distinct line of separation between the numerous varieties of iron and steel. The physical method which the author has employed showed clearly that there was no dividing line. He has adopted the plan in his researches of simply reading an unknown piece of iron or steel in its annealed state; if the figure stands above 400°, it is classed as iron; if below, as mild or hard steel, according to its magnetic capacity. This happens to agree with the classification at present in use.

Iron is by far the richest of all metals in its physical nature. It stands almost alone in its magnetic qualities and its tempering properties; and while there is an evident relation between capacity for temper and loss of magnetism when tempered, these experiments show an intimate, if not absolute, relation between the electric conductivity of iron and its magnetic capacity. There is an exact correspondence between the progressive increase of resistance and the progressive decrease of magnetic capacity. The molecular rigidity, observed by the author as the cause of hardness, gives at once decreased magnetic capacity and increased electrical resistance, and *vice versâ*. This only holds true in the limited sphere of elastic rotation. Another relation of physical to mechanical tests may be mentioned. When the electro-motive force in the magnetic balance was increased, all the readings became confused; there was no longer any fixed relation as to hardness or as to any other quality. But on again forcing the magnetism to a very high point, the figures for magnetic capacity were found to bear exactly the same relation to one another as those for tensile strength. This, however, may have been only an accident, but it gives hope that by a new method we may some day be enabled to deduce from magnetic capacity, not only electric conductivity but also tensile strength. Already a close relation between molecular rigidity and tensile strength is noticed.

In the discussion which followed this paper, Prof. W. Chandler Roberts pointed out that the cause of the curve of magnetic capacity

* *Institute of Mechanical Engineers, Proceedings*, 1884, pp. 36–60.

not quite following the percentage of carbon, was due to the large amount of manganese present in two of the specimens.

Standard Forms of Test-Pieces.—In a paper read at the meeting of the Institute of Civil Engineers held on January 22nd, Mr. W. Hackney advocated the adoption of standard forms of test-pieces for bars and plates.* The author remarked that the results obtained from determinations of the tensile strength depended upon the form of the test-piece employed, and, as was shown by J. Barba in a paper published in the *Mémoires de la Société des Ingénieurs Civils,* that test-pieces of similar form, in which the ratio of length to diameter is the same, give the same percentage of absolute elongation, whatever their size may be, and whether they are flat or round, but that it varies considerably in those of equal length, but differing in diameter, or of similar diameter but of different length. Sir Joseph Whitworth advocated the use of a test-piece having a ratio of length to diameter of 2·51 : 1. In the one used at Woolwich Arsenal it was 3·75 : 1; and in the case of the test-piece used on the Continent the ratio was 10 : 1; so that a piece of mild steel cut from the same bar, but of these different sizes, would show an elongation of 44·5 per cent., 37·5 per cent., and 28·2 per cent. respectively.

The impossibility of comparing results as to ultimate elongation obtained with test-pieces of different forms, led to the adoption of several alternative methods for comparing relative toughness, one of which was based on the fact that when a bar of ductile metal was stretched, it at first extended equally from end to end with each successive increment of load, until the maximum load it could carry had been reached, and that up to this point the percentage of elongation was absolutely independent of form. Another method was to determine the percentage of contraction of area at the point of rupture, and a third consisted in using very long test-pieces, and in rejecting the percentages of elongation of the portions of the test-piece near the breaking-point.

The author was of opinion that the standard lengths for the testing of plates should be that which was most generally adopted at the present time, namely, 8 inches, with a conventional width and thickness, and that the size of cylindrical test-pieces should be determined by experiment, so as to correspond with that of the flat bar.

In determining the standard forms, the effect produced by the

* *Proceedings of the Institute of Civil Engineers,* vol. lxxvi. pp. 70–158.

distance of the shoulders from the datum points of the test-piece on the percentage of elongation should not be disregarded. The enlargement might begin, for instance, half a diameter beyond each datum point, and its radius of curvature might be half a diameter.

In the discussion which ensued, Professor Kennedy stated the results of a series of experiments which he had been requested to make. Twenty-four test-pieces of various sizes, and having differently-shaped shoulders, were cut from a plate of basic steel. All broke in the middle or towards the end, and the tensile strength varied from 26 to 27½ tons, with an elongation of about 24 per cent. It was evident from the tests that square shoulders were radically wrong, the result being always an abnormally small extension and reduction. Professor Kennedy remarked that three points about reduction of area were worthy of notice. First, as he believed had been originally pointed out by Mr. Daniel Adamson, it was a mistake to take the final load which a piece would bear, and divide it by the final, or reduced area, and to say it was the final load; and he showed that up to the limit of elasticity the extension was proportional to the stress; but directly this point was passed the resistance of the metal suddenly collapsed, and a lesser strain sufficed to elongate it than was necessary immediately before. The second point was that reduction of area was certainly much more affected by the form of the test-piece than the extensions; and, thirdly, he had been told by Professor Bauschinger of Munich that reduction of area was affected by flaws in the metal, especially in steel, much sooner than extension. With regard to the way in which the ends of the test-pieces are held, he had compared the results obtained from pieces held in wedge-holders and from pieces made with enlarged ends and pulled from pins, and he had found practically no difference between the two methods. He further remarked that he had tested a number of pieces against each other, some polished and some simply without sharp corners, and had found that as long as no sharp corners and no injury from shears or any abrading tool are left within the limits of the test-piece, there is no difference in the results.

Testing Machine at the Royal School of Mines.—A testing machine, manufactured by L. Stuckenholz of Wetter on the Ruhr, has recently been erected in the Metallurgical Lecture Theatre of the Royal School of Mines. It is of the same type as those employed in the German Imperial Dockyards and at the Leoben School of Mines, and is arranged for shearing, bending, and crushing tests, as well as

for the determination of tensile strength. It is a multiple lever machine, the stress being applied by means of screw-gearing, the counterbalancing being effected by placing weights in a pan at the end of the long arm of the lever, or by sliding a jockey-weight along it. The lever multiplies a hundred times. In determining the tensile strength, one end of the test-piece is attached to the short arm of the lever and the other to the screw. For crushing or bending tests, as in the case of rails, the metal is pressed against the short arm of the lever by raising, by means of tie-rods connected with the screw-gearing, a long girder placed in a trough beneath the level of the floor. The shearing is effected by placing the test-piece between jaws which are connected with the screw and the short lever arm respectively, and which are, by this means, drawn asunder.

The machine is constructed for strains up to fifty tons, and was chosen on account of its simplicity and compactness. It is stated to have given complete satisfaction, and its use will enable Professor Chandler Roberts to complete the teaching of the School of Mines as regards the mechanical properties of metals and alloys, a subject which has hitherto received but little attention there.

Specifications for Steel Rivets.—The following are the latest instructions issued by the Admiralty for testing steel rivets.* The rivets are to be made from steel bars, having an ultimate tensile strength of not less than 58,000 lbs. per square inch of section, nor more than 67,000 lbs., with a minimum elongation of not less than 20 per cent. in a length of 8 inches. A portion of one bar in every fifty is to be taken for testing before being made into rivets. Pieces cut from every bar, heated uniformly to a low cherry-red, and cooled in water at 82° F., must stand bending in a press to a curve of which the inner radius is equal to the radius of the bar tested. Rivets are to be properly heated in making, and the finished rivets allowed to cool gradually. The rivets are to stand the following forge tests:—(1.) The shank to be bent double cold without fracture, to a radius equal to the radius of the shank. (2.) Bent double hot without breaking, to as small a radius as possible. (3.) Flattening of the rivet-head while hot without cracking at the edges, the head to be flattened until its diameter is 2½ times the diameter of the rivet shank. (4.) The shank of the rivet to be nicked on one side and bent over, to show the quality of the material. One rivet in every hundred to be forge-tested as a sample.

* *The Ironmonger*, vol. xxxi. p. 612.

Hadfield's "Manganese Steel."—"Manganese steel" is produced by the addition of rich ferromanganese to ingot metal in such quantities as to form a compound containing from 7 to 20 per cent. of manganese. To produce a "steel" suitable for armour-plate, about 10 per cent. of a ferromanganese containing 80 per cent. of manganese is added, while for railway purposes 11 per cent. is found most suitable, and for tools about 12 per cent.

The ferromanganese is run into the ingot metal, and thoroughly incorporated with it; the resulting product is then tapped into ingots or other suitable moulds. On cooling it is ready for use, as it requires neither tempering, rolling, forging, nor hardening, although it may be forged and rolled in the ordinary manner. It is very fluid, the castings are very free from blowholes, and the "manganese steel" does not settle so much as does the ordinary variety, neither do the castings draw so much at the junction of the thick and thin parts as those made from ordinary steel. A sample test-bar contained 12 per cent. of manganese, and bent double when cold, though hard enough for turning iron. A sample from the same ingot had a tensile strength of 42 tons to the square inch with an elongation of 20·85 per cent.

This metal has not the slightest magnetic capacity, is a very poor conductor of electricity, and instead of hardening when suddenly cooled it becomes softer and tougher.

V.—*ANALYSIS OF IRON AND STEEL.*

The Estimation of Silicon in Iron and Steel.—At the meeting of the Chemical Society on May 15th, T. Turner read a paper on this subject.* The author has estimated the silicon in samples of iron and steel containing from 0·06 to 0·22 per cent. of silica by the various methods usually employed, and comes to the conclusion that the method suggested by Watts is generally applicable, and gives, when slightly modified, accurate results. The method consists in passing pure dry chlorine over the iron borings at a red heat. The iron chloride condenses in the colder portion of the combustion tube, while the silicon chloride passes on, and is decomposed by passing through water, which, on evaporation, yields the silica. The improvement suggested by the author is the use of a Will and Varrentrapp's bulb to contain the water by which the silicon chloride is decomposed.

* *Journal of the Chemical Society*, 1884, pp. 260–266.

This process has the great advantage of distinguishing between unoxidised silicon and slag, while it gives rapid and accurate results with all classes of iron, and hence may help to supply a want of the iron analyst.

Spectroscopic Examination of the Vapours Evolved on Heating Iron.—J. Parry of Ebbw Vale describes* the results of a spectroscopic examination of the vapours evolved on heating iron at atmospheric pressure.

Spiegeleisen fused in a crucible evolved a fume in which were detected zinc, copper, manganese, calcium, and, with less certainty, magnesium.

Bessemer pig iron similarly treated gave copper, manganese, calcium, either lead or arsenic, as well as a gas burning with a flame resembling that of carbonic oxide.

Bessemer pig iron burnt in a current of oxygen at a dull red heat gave evidence of the presence of copper, manganese, &c., as before, but in a greater degree.

Spanish iron ore reduced in a crucible with charcoal at a temperature sufficiently high to form a button of fused metal, evolved zinc, copper, and manganese.

Volumetric Estimation of Iron.—In the analytical results obtained by different chemists, differences in the percentage of iron in an iron ore may be frequently observed. These differences amount to 1 per cent. and above, while the numbers obtained by the same chemists may agree within one-tenth of a per cent. In all cases where volumetric methods are employed, the most important point to be considered is how to obtain the standard solution invariably of an accurately known strength, and it is from a variation in the methods employed for this purpose that a large amount of the variation in the results above alluded to is due. It seems simple enough to weigh out the exact amount of potassium dichromate and dissolve it in a known volume of pure distilled water. Instead of fusing the salt, as recommended by some chemists, it is best, according to R. W. Atkinson,† to grind up the purest crystals, and to dry them in a steam-oven for several hours before weighing out. It is always safer to standardise it before use. Absolutely pure ferric oxide is the best substance for this purpose, but it is somewhat difficult to prepare. In a large number of cases steel borings are now used. The composition of the

* *Chemical News*, vol. xlix. p. 241.
† *Ibid.* pp. 117, 217.

steel is first determined. A weighed quantity is then dissolved in dilute sulphuric acid, boiled, and titrated by means of dichromate. It is assumed that the hydrocarbons formed during the solution of the steel are without effect upon it; but the results obtained by the author cast some doubt upon this assumption. In order to arrive at the true value of the solution in terms of metallic iron, three series of experiments have been made with solutions of potassium dichromate prepared on eight different occasions. The composition of the steel (Bessemer rail) used in the experiments was as follows :—

Fe	C	Si	S	P	Mn	Total.
97·90	0·50	0·08	0·15	0·09	1·50	100·22.

In the first column is given the strength of the solutions as indicated by a specimen of granulated sulphate of iron and ammonium. In the second column the standard of each solution is given, determined by dissolving a known weight of steel in nitric acid. In the third column are given the numbers obtained by dissolving the same steel in dilute sulphuric acid, boiling and titrating the solution.

No. of Solution.	Sulphate of Iron and Ammonium.	Steel Dissolved in Nitric Acid.	Steel Dissolved in Sulphuric Acid.
A	0·005803	...	0·005516
B	0·005890	...	0·005852
C	0·004999	...	0·004961
D	0·005022	0·005031	0·004990
E	0.005990	0·005982	0·005950
F	0·005004	0·005009	0·004977
G	0·004996	0·004996	0·004965
H	0·005981	0·005979	0·005946
Average D to H	0·005399	0·005399	0·005365

It will be observed that while the average strength of the solutions formed by the use of sulphate of iron and ammonium agrees very closely with that obtained by dissolving the steel in nitric acid, both are considerably higher than the number obtained by dissolving the steel in sulphuric acid. Too low results will, therefore, always be obtained when the dichromate solution is standardised by dissolving steel in sulphuric acid. The only explanation seems to be that the hydrocarbons liberated have some reducing action upon potassium dichromate. It is, however, remarkable that the differences in solution F seem almost as marked as in the other solutions, although in that case a mild steel with but 0·14 per cent. of carbon was employed.

Some points in the treatment of an iron ore for analysis may not be without interest.

A fair sample of the ore is ground sufficiently fine to pass through a sieve of 120 meshes to the linear inch, dried at 100° C., and when cold, portions of about 0·5 to 0·6 grammes are weighed out for analysis. On account of the fine state of division of the ore, it absorbs moisture greedily during weighing, and this forms an important source of error which is greatest in the case of soft ores. The next step is to dissolve the weighed sample in a conical flask with from 10 to 15 c.c. strong hydrochloric acid, covering the flask with a watch-glass. The author has never found the ferric chloride to be volatile at 100° C., and believes that no such loss is to be feared. When the ore is completely dissolved it is reduced to the ferrous state, the reducing agents mainly employed being zinc, stannous chloride, and sulphurous acid in the form of one of its salts.

Reduction of zinc is trustworthy if it contains no iron, or if the quantity at present is allowed for. Zinc, however, is not a good reducing agent, being too slow in its action, and the resulting zinc chloride rendering the development of the blue colour on the addition of potassic ferricyanide much slower. Finally, the colour towards the end of the titration becomes so faint that it is impossible to distinguish the presence of an amount of iron less than one or two-tenths per cent. of the iron contained in the ore.

The reduction with zinc is, however, much to be preferred to the reduction by stannous chloride. A strongly acid solution of stannous chloride is used. The portion of the ore dissolved in hydrochloric acid is diluted with boiling water, stannous chloride is added, and the solution is then boiled till the yellow colour has disappeared, the excess of reducing agent being destroyed by the addition of an oxidising agent until a drop of the solution gives a faint red colouration with potassic sulphocyanide. It is upon the accuracy with which this re-oxidation is performed that the correctness of the result depends.

The best method for the reduction of the ferric salt is the employment of a concentrated solution of ammonic bisulphite, sodic bisulphite being by no means so trustworthy as the ammonic salt, it being much more difficult to get rid of the last traces of sulphurous acid when the latter is used. One great advantage that this method of reduction possesses over the other two, lies in the formation of a solution which is practically that of ammonio-ferrous sulphate, one of the most stable of the ferrous salts, and consequently there is less danger of oxidation while transferring it from the flask to the basin, than is the case with the acid solutions of ferrous chloride obtained by the two former methods

of reduction. A further advantage lies in the fact that the end reaction with potassic ferricyanide is very clear and delicate, so that there is no difficulty in distinguishing the addition of $\frac{1}{20}$th c.c. of dichromate, (strength 1 c.c. = 0·005 gramme iron), equivalent to 0·0005 gramme iron. The results are very concordant.

The potassic ferricyandic solution should be kept in the dark to prevent decomposition, and similarly the drop of solution to which the ferricyanide has been added should be kept shaded until the reaction has taken place, to prevent the drop turning blue by reduction under the influence of daylight.

VI.—*STATISTICS.*

Mineral Statistics for 1882.—Since the publication of the last volume of this Journal, the official mineral statistics for 1882 have been issued.* The exceptional delay was caused by the transfer of the Mining Record Office from the Museum of Practical Geology to the Home Office.

During the year 1882 the production of iron ore in the United Kingdom was 18,031,957 tons, worth £5,779,285; 5872 tons of bog iron ore, worth £1957, were also produced. Including the foreign ores imported, the total quantity of iron ore available for the blast furnace was 21,702,930 tons.

There were 180 ironworks in operation with 929 blast furnaces, 570 of which were in blast; 8,586,680 tons of pig iron were made, and 17,796,301 tons of coal used. There were 335 iron mills and forges, possessing a plant of 5707 puddling furnaces and 917 rolling mills. The total production of puddled bar iron was 2,841,534 tons. The production of Bessemer steel ingots was 1,673,649 tons; thirty Bessemer converters being in operation. In the open-hearth steelworks there were 158 furnaces; the production of open-hearth steel being 436,000 tons; 156,499,977 tons of coal, worth £44,118,409, were produced in the United Kingdom from 3759 collieries.

Coal.—The Reports of the Inspectors of Mines for 1883 show that the production of coal in Great Britain and Ireland amounted to 163,737,327 tons.† The total number of persons employed in and

* "Mineral Statistics of the United Kingdom for the Year 1882. Prepared by Her Majesty's Inspectors of Mines." London, 1884.

† "Summaries of the Reports of the Inspectors of Mines to Her Majesty's Secretary of State, and Mineral Statistics for the Year 1883." London, 1884, p. 8.

about the mines under the Coal Mines Act was 514,933 in 1883, against 503,987 in 1882. There were 921 separate fatal accidents in these mines, as against 876 in 1882. The total loss of life is reported as 1054 for the year 1883. There were 25 explosions of fire-damp, with a loss of 134 lives; but more lives were lost in consequence of falls of roofs and slides in the mines, 469 last year, against 468 in 1882. The loss of life in the shafts was 97, and 246 lives were lost from explosions of powder and other causes in the mine. The loss of life on the surface was 108.

Iron Ore.—The production of iron ore in the United Kingdom during 1883 was, according to the official statistics, 17,383,046 tons valued at £5,122,381. Of this total, 11,495,401 tons were produced from the mines under the Coal Mines Act; the remainder being produced from metalliferous mines and open workings.

Summary of the Iron Trade Statistics.—The Secretary of the British Iron Trade Association has compiled the following summary for 1883:—

	Tons.
Production of pig iron	8,490,224
Stocks of pig iron on December 31st	1,698,976
Home consumption of pig iron	8,449,368
Production of hæmatite iron	3,287,000
,, spiegeleisen	208,445
,, puddled bar	2,730,504
,, Bessemer steel ingots	1,553,380
,, Bessemer steel rails	1,097,174
,, open-hearth steel	455,500
,, coal	163,737,327
,, ironstone in coal-measures	11,495,401
Shipbuilding, tonnage constructed	1,329,604
,, in course of construction at end of year	729,446
Exports of pig iron from United Kingdom	1,564,137
,, railroad iron	971,662
,, hoops, sheets, and plates	348,304
,, bars, angles, rods	287,900
,, tin plates	269,367
,, wire	62,784
,, steel, unwrought	73,056
,, old iron	97,579
,, all other iron	355,868
Total exports of iron and steel	4,044,273

Exports.—The exports of iron and steel from the United Kingdom during the six months from January 1st to June 30th were, according to the Board of Trade Returns, as follows:—

Description.	Quantity. 1883.	Quantity. 1884.	Value. 1883.	Value. 1884.
	Tons.	Tons.	£	£
Pig iron	714,139	648,463	1,886,192	1,525,370
Bar, angle, bolt, and rod	144,613	139,261	1,032,525	933,733
Railroad of all sorts	507,069	383,850	3,225,869	2,168,836
Wire of iron or steel and manufactures thereof, except telegraph wires	33,137	25,728	507,461	345,069
Hoops, sheets, and boiler and armour plates, including galvanised sheets	169,066	168,703	1,900,617	1,843,381
Tin plates	131,363	144,751	2,325,226	2,424,106
Cast and wrought and all other manufactures except ordnance	173,763	193,091	2,343,355	2,309,725
Old for remanufacture	48,587	32.790	172,251	108,980
Steel unwrought	43,749	28,143	741,197	587,517
Manufactures of steel, or steel and iron combined	6,893	6,391	323,764	223,173
Total of iron and steel	1,972,379	1,771,171	14,458,457	12,469,890
Foreign iron bars	31,141	25,636	292,453	224,481
Foreign steel unwrought	2,237	2,325	30,210	23,113
Foreign manufactures unenumerated	32,080	22,241	425,600	363,588
Total exports of foreign iron and steel	65,458	50,202	748,263	611,182
Iron rails	16,291	7,322	111,452	49,602
Steel rails	391,953	293,818	2,358,844	1,589,277
Total of iron and steel rails	408,244	301,140	2,470,296	1,638,879

Furnaces in and out of Blast.—The following table shows the condition of the blast furnaces of the United Kingdom on July 1, 1884 :*—

	In.	Out.	Rebuilding and Repairing.	Building.
South Staffordshire	36	78	1	2
North Staffordshire	23	17	...	...
Shropshire	6	18	...	...
Northamptonshire	15	11	...	...
Lincolnshire	17	4	...	1
Cleveland	99	57	...	...
Yorkshire (West Riding)	24	20	1	...
Derby, Nottingham, Leicester	40	18	1	...
Lancashire, Cumberland	66	39	...	...
Gloucestershire	1	7	...	...
Hants, Wilts, Somerset	1	7	...	...
North Wales	4	6	...	...
South Wales, Monmouthshire	48	88	1	1
Scotland	95	51	...	...
Totals	475	421	4	4

* *The London Iron Trade Exchange*, July 5.

Shipbuilding.—The total gross tonnage of new vessels launched in the United Kingdom during 1883 was, according to the returns of the British Iron Trade Association, 1,329,604 tons, against 1,240,824 tons in 1882, the increase for 1883 being 88,780 tons. Of the 1,329,604 tons of new shipping constructed in 1883, 1,116,555 tons were built to Lloyds' survey in steel, iron, and wood respectively, as follows:—

	Number of Vessels.	Gross Tonnage.
Steel	109	166,428
Iron	644	933,774
Wood	95	16,353

The total tonnage of vessels of iron, steel, and wood respectively classed in each of the three leading classification Societies during the year 1883 was as follows:—

Society.	Iron.	Steel.	Wood.	Totals.
Lloyds' Register . .	933,774	166,428	16,353	1,116,555
Liverpool Underwriters .	100,075	36,552	...	136,627
Bureau Veritas . .	180,594	22,775	...	203,369
Totals . .	1,214,443	225,755	16,353	1,456,551

AFRICA.

The Metalliferous Zone of North-West Africa.—The general distinguishing geological feature of the whole of North-West Africa is the great upheaval southwards of the eruptive zone extending from Madeira and the western islands of Southern Italy. Regarding this as an anticlinal, the great dip towards the African coast gives an exposure of a succession of beds of old Cretaceous or late Carboniferous date, at certain points of which the iron ore deposits assume importance.*

In Morocco there are beds of hæmatite of considerable size, and their continuity and reappearance westwards is now an ascertained fact.

Commencing from the Tunisian frontier, the Mediterranean sea-board offers an abundance of payable ore at various points, and these deposits were very extensively worked by the Romans, forming, indeed, their main supply.

The most productive Algerian mines furnish a spathic carbonate containing 60 per cent. of ferrous oxide, and a hæmatite containing 92 per cent. of ferric oxide. The composition of the Algerian ore is exceedingly uniform, and it is almost entirely free from sulphur and phosphorus.

A reappearance of these beds occurs as far west as the confines of the provinces of Rihamina and Dukkala in South Morocco. The deposits consist of red hæmatite, and show an outcrop of very extensive area. The ore is for the most part of a silky fibrous type, though inclining, here and there, to the reniform character found in the Algerian ore. It rests upon a limestone of a similar nature, and this upon older shales, which are frequently tilted almost into a vertical position. Specimens of iron-sand brought from the Sahara caravan route either to Tafilelt or Timbuctoo prove the reappearance of these iron ore beds south of the Atlas ranges.

* *The Ironmonger*, vol. xxxi. p. 729.

Production of Iron Ore in Algeria.—The production of iron ore in Algeria during 1882 was, according to the recently issued official statistics,* 567,119 tons, representing a value of £218,578.

Six mines and eight diggings were working, and 2120 hands were employed. The exportation of iron ores was to:—

	Tons.
France	302,000
England	132,000
Germany	31,000
Belgium	10,000
United States	122,000

* *Statistique de l'Industrie minérale pour l'Année* 1882, p. 40.

AUSTRALASIA.

Coalfields of Australasia.—It is estimated that the distribution of coal measures in Australia embraces an area of 270,000 square miles; while the ascertained coal area amounts to 40,000 square miles. The coalfields of New South Wales embrace an area of 24,840 square miles, or about one-twelfth of that of the entire colony. The coal measures present from 11 to 18 different seams, and are found at various levels, from 450 feet below to 1500 feet above sea-level. The principal collieries are in the vicinity of Newcastle. The coal measures are about 500 feet thick; the lowest seam, which is the one generally worked, is from 8 to 15 feet in thickness. The coal is bituminous, and of excellent quality. The output in 1882 was, according to the official statistics,* 2,109,282 tons, valued at £948,965. This output largely exceeds that of any previous year. There were 39 collieries in operation, and 4647 workmen were employed. From the first working of the coalfields down to the end of 1882, the total yield has been 26,042,806 tons. The home consumption of coal amounted in 1882 to 847,737 tons, while the total quantity exported was to 1,261,545 tons.

In Queensland, though immense coalfields are known to exist, they remain for the most part undeveloped on account of the difficulties of transportation. In Victoria coal of good quality is found in the Cape Patterson, Westernport, Gippsland, and Coloraine districts, but up to the present time no seams of sufficient thickness to make the working of the mines remunerative have been discovered. In Tasmania coal is found in various parts of the island, and several mines are being worked, producing a total annual yield of about 12,000 tons.

In New Zealand collieries are being worked in the provinces of Auckland, Canterbury, Nelson, and Otago. Accurate surveys of the Mount Rochfort coalfield show it to contain 140,000,000 tons of bituminous coal of excellent quality; the seams being from 10 to 40

* *Annual Report of the Department of Mines, New South Wales, for the Year* 1882, p. 19.

feet thick. The Brunner coalmine on the Grey River has an available working area of 30 acres, the seam being 18 feet thick.

The Iron Ores of New South Wales are among the richest in the world, the deposits being numerous and practically inexhaustible ; but the colonial iron industries are as yet of limited extent in consequence of the small amount of capital expended in their development.

The Esk Bank Company continue to be the only makers of iron in the Colony. During the year 1882 they made 4320 tons of pig iron, 2139 tons of finished iron, and 1016 tons of castings.

Iron Ore in New Zealand.—A seam of hæmatite which has been struck in the province of Otago is likely to become of some value.* It is asserted that the ore is superior to the ordinary hæmatite used at the Hillside Government Workshops, and it has been successfully tried along with both English and Nelson hæmatite. The New Zealand Iron and Woodware Company are erecting machinery for the purpose of crushing the ore and making it marketable. The latter firm has already taken delivery of about twenty loads, and others in the same line of business have tried samples of it with satisfactory results. Should the seam increase in thickness as it shows signs of doing, and should it be of very considerable extent, there is no doubt that a profitable return will be the result. The Government analyst has not, as yet, tested a sample.

Treatment of Titaniferous Iron-Sand.—J. Davis of the Mossend Steelworks states that he has employed the Siemens rotator very successfully for the reduction of the titaniferous iron-sand of New Zealand, and that no ore he has ever tried was so well adapted for direct reduction as titanic sand.

Analysis of Titanic Sand.

	Per cent.
Ferric oxide	67·04
Ferrous oxide	30·17
Manganese oxide	0·22
Alumina	0·16
Lime	trace
Magnesia	trace
Sulphuric anhydride	trace
Phosphoric anhydride	0·03
Silica	0·51
Titanic anhydride	1·64
Moisture	0·14
Total	99·91

* *London Iron Trade Exchange*, 1884, July 5, p. 20.

Annealing Iron Castings.—It is stated that an accident at a foundry in Melbourne, by which a red-hot iron casting was dropped into water and was afterwards found to have become remarkably soft, originated a process for annealing chilled and other iron castings, which has just been patented in the United Kingdom. It consists in plunging the metal when it is reduced to a very dull red heat, and just as the redness is about to disappear, into a mixture of treacle and water having a specific gravity of 1·005. The inventors do not confine themselves to this solution only, but it is found to give better results than any other they have tried. The process is said to soften castings in such a degree that they can be punched, bored, and tapped as readily as wrought metal.

AUSTRIA.

Analyses of Iron Ores, Iron, and Steel.—Dr. E. Priwoznik has recently published* details of the analyses which were made last year at the Government Assay Office in Vienna.

The following tables give some of the results obtained :—

	a	*b*	*c*	*d*
Ferrous oxide	38·70	41·40	38·31	...
Ferric oxide	4·07	2·93	...	60·57
Iron sulphide	0·96	0·32	0·28	...
Copper	trace	trace	...	CuO 0·008
Antimony	trace	trace	...	...
Manganese oxide	3·67	2·86	1·96	trace
Cobalt and nickel	trace	trace	...	trace
Alumina	2·11	0·75	2·83	1·60
Lime	1·60	0·65	1·30	0·50
Magnesia	4·31	4·47	4·22	0·18
Silica (free and combined)	11·02	13·17	20·85	24·55
Sulphuric anhydride	0·602	0·567	0·277	0·05
Phosphoric anhydride	0·218	0·061	0·055	2·38
Graphite	0·22	trace	$\left\{\begin{matrix} K_2O \\ Na_2O \end{matrix}\right\}$ 0·38	As_2O_5 0·02
Carbonic anhydride	31·52	32·17	29·64	10·05
Water	1·05	0·80	...	
	100·050	100·148	100·102	99·908

a, *b*, *c*, spathic iron ores from Betlér ; *d*, hæmatite from Rokycan, Bohemia.

	e	*f*	*g*	*h*	*i*	*k*	*l*	*m*	*n*
Chemically combined carbon	2·442	0·370	0·257	0·164	0·280	0·196	0·818	0·298	0·235
Graphite	1·631	3·414	3·425	...	...	...	3·070	...	...
Silicon	0·684	3·640	1·353	0·023	0·050	0·037	2·286	0·070	0·010
Phosphorus	0·068	0·701	0·059	0·067	0·073	0·071	0·083	0·096	0·060
Sulphur	0·025	0·015	0·011	0·011	0·025	0·036	0·019	0·029	0·019
Copper	trace	0·252	0·029	0·060	0·005	0·005	trace	0·005	trace
Cobalt and nickel	trace	0·030	0·019	0·008	trace	trace	0·030	0·015	0·004
Manganese	2·992	1·834	3·414	0·088	0·215	0·190	4·088	0·202	0·076
Iron (by difference)	92·158	89·744	91·433	99·579	99·352	99·465	89·606	99·285	99·596
	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000	100·000

e, mottled pig iron from Hieflau, Styria ; *f*, grey pig iron, Witkowitz, Mähren ; *g*, grey pig iron, and *h*, steel from Neuberg, Styria ; *i* and *k*, Siemens-Martin ingot metal from the Austrian Alpine Mining Company ; *l*, grey pig iron ; *m* and *n*, Bessemer steels from the same Company.

* *Leoben Jahrbuch*, vol. xxxii. pp. 32–48.

Formation of Good Coke from a Badly Caking Coal.—Some experiments have recently been made at the Trzynietz Works * to produce a good dense coke from a coal which, although very pure and free from phosphoric acid, did not cake at all well. The desired result was obtained by submitting the coal when in a fine state of division to compression: the spaces between the pieces of coal were thus considerably reduced, and the comparatively small quantity of tar which was formed on coking served to cement together the powder. The total out-turn by this method of coking was from 3 to 5 per cent. higher than that by the method usually employed.

Coal in Bosnia.—Experimental borings have for some months been carried on near Mostár, and have now met with success; † a coal-seam having been met with 26 yards beneath the surface. The seam is 30 feet thick, and has a longitudinal extent of nearly two miles. The coal is of excellent quality.

Electrical Transmission of Power at Thallern Colliery.—An interesting application of electrical transmission of power has recently been made at the Thallern Colliery on the Danube.‡ At the end of the main road, 900 yards from the shaft, there used formerly to be a steam pump, which rendered the atmosphere of the mine unbearable. Recourse has now been had to an electrical transmission of power, which has been working satisfactorily for four months. The great advantage of the change is, that the temperature of the pit has been reduced 14°, and a considerable saving of coal effected.

Regeneration of Blast-Furnace Gases.—Prof. von Ehrenwerth of Leoben proposes § a process for increasing the calorific power of blast-furnace gases, by which they are converted into a gaseous fuel superior to any obtainable in ordinary producers. The apparatus consists of a cylindrical furnace which is charged with fuel from above by means of a bell and hopper; while two rows of tuyeres at the bottom supply blast and blast-furnace gas respectively. By combustion within this generator, the carbonic anhydride of the blast-furnace gas will be almost entirely converted into carbonic oxide. The resulting gas will therefore consist partly of ordinary producer gas, and partly of blast-

* *Chemiker Zeitung*, vol. viii. p. 717.

† *Berggeist*, vol. xxix. p. 163.

‡ *Oesterreichische Zeitschrift für Berg- und Huttenwesen*, vol. xxxii. p. 182.

§ "Die Regenerirung der Hohöfen Gichtgase." Leipzig, 1883.

furnace gas, the carbonic anhydride of which has been converted, by the addition of more carbon, into carbonic oxide. The latter portion is a very rich gas, as about half its oxygen is derived from a source free from nitrogen, namely, from the ore smelted in the blast furnace. Austrian charcoal blast-furnace gas contains, on an average, 55 per cent. of nitrogen. The resulting gas, after the addition of carbon, consists of 48·5 per cent. carbonic oxide and only 51·5 nitrogen; while gas made in ordinary producers with air contains about 65 per cent. of nitrogen. The reduction of the carbonic anhydride to carbonic oxide will absorb a certain amount of heat, and this is supplied by the combustion of another portion of the solid fuel with air. The author calculates that 100 kilogrammes blast-furnace gas will require a total of 19·25 kilogrammes coke or coal with 80 per cent. carbon, and 57·72 kilogrammes air. The regenerated gas would then be composed of 42·42 per cent. CO, 21 CH_4, 15 H, and 57·22 N; provided that all the carbonic anhydride was converted into carbonic oxide.

The regenerated gas would be an excellent fuel for works where the open-hearth process is in operation, and its preparation deserves the special consideration of the Styrian ironmasters and others similarly situated. The author expresses his conviction that the open-hearth process is far more suitable for such small works than the Bessemer process.

Iron and Steel in Austro-Hungary.—The ores of iron occurring in Styria and Carinthia are principally spathic carbonates and brown hæmatites; the ores of Bohemia contain a large amount of phosphorus, as also do those which occur so abundantly in the Carpathian Mountains. The mines are, unfortunately, usually too far distant from any coal deposits to permit of the use of coke for the manufacture of pig iron; charcoal is, however, easily obtained, as forests abound all over the Empire. The total area so covered amounts to 188,000 square kilometres. About 6,000,000 hectolitres of charcoal are made annually, and its price is about twenty-five francs per 1000 kilogrammes. One-half of the total output of pig iron is made with charcoal. There are but few deposits of coal and lignite, the total output of coal being only 5,000,000 to 6,000,000 tons, together with 12,000,000 to 15,000,000 tons of lignite. In Hungary there are deposits of lignite having a known length of 20 kilometres and a thickness of 61 metres.

There are in Austro-Hungary 279 blast furnaces, of which 166 are in blast. They are principally of the old type, working with cold blast. The four chief works produce 500,000 metric tons annually. There

are in Austria twelve Bessemer steelworks, possessing thirty-four converters, while in Hungary there are but six works. In Bohemia the phosphoric pig is treated by the basic process; lignite is used as fuel, and costs but two to three francs per ton. There are three Siemens-Martin steelworks in Austria and two in Hungary. Lignite is used in the gas-generators. There are very few crucible steel manufactories. Puddling furnaces using coal as fuel are only found in Bohemia and Moravia. In Styria lignite is used, and is burnt on step-grates; and in Hungary the fuel consists of gas from lignites or charcoal. Steel plates are made at Neuberg, rolls of a diameter of 0·8 metre being used. Rails are made at all the steelworks. In 1882 ten works produced 125,000 metric tons. The rolling-mills are in each case reversible, and gas reheating furnaces are employed. The rails weigh from 30 to 35 kilogrammes per metre, and are from 7 to 9 metres long. About 3000 tons of tyres are turned out annually.*

Experiments on the Welding of Bessemer Iron. — The extensive experiments on this subject carried out for the Berlin Society of Arts, led Dr. Wedding to report (this Journal, 1883, p. 425) that perfectly good welds were the exception, and that therefore all welding of ingot iron should be avoided. In Austria, however, ingot iron, whether made by the Bessemer or open-hearth process, is generally considered to be weldable. For example, the following severe test of ship-angle iron is exacted by the Imperial Navy:—One of the sides of the angle is cut across, then bent at right angles, and the overlapping parts welded together. After cooling, the angle is again straightened, and the weld must prove perfectly sound; no signs of cracking being allowed. The Austrian Bessemer iron stands this test, provided the smith is accustomed to the operation. The metal contains 0·2 to 0·25 carbon, and has a tensile strength of 40 to 50 kilogrammes per square millimetre. The material experimented on by W. Hupfeld † of Prevali was the ordinary Bessemer metal as used for rails on branch lines in Austria. It is blown directly from pig iron of a fine grey fracture, with from 2 to 2·5 per cent. of silicon, 5 to 6 manganese, 3 to 3·5 carbon, 0·03 to 0·04 phosphorus, 0·01 to 0·02 sulphur, and traces of copper; the fuel used in the blast furnace being equal quantities of charcoal and coke. The charge consisted of 6 parts of Hüttenberg white ore, 3 parts brown ore, 1 part puddling

* *Mémoires de la Société des Ingénieurs Civils*, February 1.
† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxii. p. 105.

cinders, and 2 parts limestone. The converter charge of 7 tons is blown down to 0·1 per cent. carbon, and recarburised with 4 per cent. of cold, or 0·1 per cent. of molten spiegeleisen containing 12 per cent. manganese. The charges are hot, and usually require an addition of 12 to 15 per cent. of cold metal. The ingots are cast as cold as possible.

During each of 27 blows two test-pieces, 0·3 metre long and 0·07 metre square, were cast. One of each pair was broken into two pieces, each of which was forged down and drawn out at one side to a wedge, and the two were then welded together, with a bearing surface of 0·07 metre, in the ordinary manner with sand. The welded piece was then reheated, and forged into square bars 0·018 metre thick and 0·35 metre long. These were then turned into test-bars of 0·015 metre diameter, and well polished. Corresponding test-bars of the unbroken sample were prepared. The load in the testing-machine was applied by a steady flow of water into a cylinder, the weight of which acts vertically on the bar. All samples behaved very much alike. At a load of 5500 to 6000 kilogrammes, a sudden elongation of 4 to 7 millimetres was observed, which distinctly marked the limit of elasticity. By stopping the inflow of water for about a minute, the load could be again gradually increased. The specimens were always strongly drawn in at the point of fracture, the one part having a convex head fitting into a cavity of 1½ to 2 millimetres depth in the other. No difference in the appearance of the welded and unwelded test-bars, and no trace of a seam were perceptible. The fracture had always a fine grey velvety appearance.

The table on page 227 gives the results obtained with the welded and unwelded specimens; the diameter of the test-bars being, in all cases, 0·015 metre, and the distance between the marks 0·200 metre.

The average reduction in the tensile strength in the welded specimen is 1·75 per cent., and in no case is the difference more than 5 per cent. In some cases there is no difference at all. No notable influence of the chemical composition is perceptible. It is, however, the general experience with Austrian steels that with more than 0·45 per cent. of silicon weldability ceases, particularly in the presence of much carbon. A correcting influence of manganese, which at Prevali always increases with the silicon, has not been observed. The author considers that Bessemer metal, if similar in composition to the Austrian rail metal, can easily and with certainty be welded. He cannot, however, account for the contradictory results obtained at Berlin, except on the ground

of insufficient practical experience on the part of the smiths who prepared the samples. Thousands of welds are made annually at Prevali, failures occurring very rarely.

No.	Bessemer Iron not Welded.			Bessemer Iron Welded.			Analysis.		
	Tensile Strength, kilos. per sq. mm.	Elongation per cent.	Contraction per cent.	Tensile Strength, kilos. per sq. mm.	Elongation per cent.	Contraction per cent.	Si.	C.	Mn.
1	...	...	...	52·0	19·00	39·8	...	...	...
2	59·5	17·00	49·3	59·5	17·00	49·3	...	...	...
3	...	...	...	58·4	17·50	48·8	...	...	...
4	...	...	...	51·7	17·50	52·4	...	...	...
5	...	...	...	51·2	17·50	53·6	0·09	0·21	0·33
6	54·9	17·50	58·7	53·9	18·00	63·2	...	...	...
7	54·2	17·50	60·2	52·3	19·25	56·2	0·09	0·20	0·49
8	56·6	19·00	57·4	56·6	19·00	57·4	0·14	0·21	0·30
9	55·8	19·00	54·0	55·3	17·50	43·7	0·12	0·22	0·45
10	54·3	21·50	58·7	52·5	16·50	58·5	0·10	0·20	0·46
11	55·9	20·00	54·0	56·0	18 00	56·5	0·16	0·23	0·60
12	53·1	20·50	57·4	53·1	20·50	57·4	0·12	0·20	0·41
13	52·2	21·00	59·2	52·4	21·75	58·6	0·07	0·19	0·35
14	58·0	18·75	60·0	57·0	19·50	59·3	0·25	0·20	0·70
15	54·7	18·00	54·6	54·1	21·00	57·5	0·13	0·20	0·43
16	55·3	19·00	55·8	54·7	22·00	59·3	0·15	0·21	0·44
17	...	...	...	57·4	21·75	57·0	0·16	0·20	0·59
18	56·1	19·50	51·8	54·7	20·50	52·2	0·14	0·21	0·54
19	56·3	20·50	56·7	55·5	18·00	56·9	0·10	0·26	0·46
20	54·1	19·50	60·0	54·1	19·50	60·0	0·10	0·24	0·48
21	50·5	20·50	59·7	50·8	19·00	64·6	0·05	0·21	0·28
22	52·4	19·25	60·0	49·2	13·00	45·2	0·08	0·20	0·32
23	61·5	17·00	60·0	60·4	19·50	54·6	0·30	0·20	0·85
24	50·6	17·50	64·0	51·8	22·00	63·7	0·09	0·20	0·30
25	53·4	19·00	60·9	54·1	22·50	58·7	0·05	0·21	0·32
26	58·0	16·00	58·3	56·8	19·00	58·1	0·18	0·20	0·61
27	60·3	18·00	54·4	60·8	19·50	54·6	0·26	0·23	0·72
Average	55·3	18·80	57·5	54·6	19·10	55·4	0·133	0·21	0·476

The Resistance of Bohemian Iron Wire in Drawing.—Prof. A. Vávra of Prague, in a recent article on this subject,* states that Bohemian iron is rich in phosphorus and other impurities, and is consequently remarkable for its great hardness and high limits of elasticity; it displays greater resistance in wire-drawing than softer varieties of iron. A fresh series of observations on the resistance of Bohemian iron wire was considered necessary, as the older experiments of Payen, Egen, and others were made with wires of various diameters and of softer foreign material; and when calculations were attempted with their help, impossible values were obtained. It is also a well-known practical experience that the constructive proportions of Rhenish wire-mills cannot be directly applied to Bohemian material.

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxii. p. 199.

The following tables, I. and II., give the author's experimental observations, from which the results given in Table III. were calculated :—

TABLE I.

Diameter of Wire.		Average Breaking Strain, kilos. per sq. mm.	Velocity of the Drawn Wire, m.	Number of Wires Drawn in Each of the Experiments.							
Before Drawing, mm.	After Drawing, mm.			I.	II.	III.	IV.	V.	VI.	VII.	VIII.
7·00	6·12	43·7	0·61	2	2	1	...	...	...	...	...
6·12	5·21	44·3	0·68	...	2	2	1	2	...	...	...
5·21	4·39	45·0	0·85	...	...	...	...	...	2	...	...
4·39	3·70	46·0		6	...	...	...	...	...	3	3
3·70	3·29	48·0		...	4	4	5	2	...	...	...
3·29	2·74	50·0		...	...	...	...	...	4	...	...
2·74	2·38	51·1		...	...	2	1	1	...	...	...
2·38	2·24	...	1·01	...	...	...	...	...	...	...	...
2·24	1·80	(54·44)		2	2	...	...	...	2	...	...
1·80	0·60	(61·67)	0·76	10	10	10	10	10	10	10	10

During each of the experiments no work was done in the mill except the drawing of the number of wires entered in the table, so that the whole useful work of the engine was equal to the drawing resistance together with the resistance of the moving machinery.

TABLE II.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Indicated duty of the engine	27·21	29·85	24·17	26·88	30·38	38·40	20·56	21·74
Do. when not drawing	7·90	7·92	8·20	8·20	8·20	8·20	8·20	8·20
Revolutions of the engine per minute	30·00	30·25	45·00	45·00	45·00	45·00	45·00	45·00
Work expended in drawing, metre-kilogrammes . .	1293	1460	1070	1251	1485	2025	828	789

The chief dimensions of the engine were :—Diameter of cylinder, 0·425 metre ; stroke of piston, 0·840 metre ; external diameter of fly-wheel, 3·492 metre ; breadth of fly-wheel rim (axial), 0·158 metre ; height of fly-wheel rim (radial), 0·316 metre. In calculating the work expended in drawing, the co-efficient of friction was taken as 0·12. This was not determined by experiment, so the results are not strictly correct.

The motion was transmitted from the fly-wheel shaft to the main driving-shaft, from which ten draw-benches were worked by means of

toothed wheels. The whole machinery was in excellent working order.

TABLE III.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Total wire sections before drawing	187·5	198·4	163·9	100·9	98·0	96·3	57·2	57·2
Total wire sections after drawing	137·9	150·0	124·5	77·8	73·6	68·5	41·8	41·8
Total reduction of sections	49·6	48·4	39·4	23·1	24·4	27·8	15·4	15·4
Average velocity in meters per second	0·49	0·47	0·73	0·79	0·74	0·88	0·83	0·83
Proportion of resistances	2·78	3·10	3·17	3·37	3·02	2·46	2·72	2·72
Tension of wire during drawing	18·9	20·7	11·8	17·8	27·3	33·6	23·9	22·8
Specific drawing resistance	52·8	64·0	37·3	68·6	82·3	80·3	64·8	61·8
Average diameter of all wires	3·0	3·1	2·9	2·4	2·5	2·2	2·1	2·1
Average breaking strain	46·6	44·9	46·6	47·8	46·3	50·0	50·0	50·0

From this table the following averages may be calculated :—

Mean tension of wire at the limit of elasticity . . $e = 35{\cdot}4$
Mean tension of wire at rupture . . . . . . $s^1 = 47{\cdot}8$
Mean tension of wire during drawing in diminished part $p = 22{\cdot}1$
Mean specific drawing resistance . . . . . . $k = 64{\cdot}0$

All the results are given in kilogrammes per square millimetre.

From these results the following ratios may be deduced :—

$$\frac{p}{e} = 0{\cdot}6 \qquad \frac{k}{s^1} = 1{\cdot}34$$

$$\frac{p}{s^1} = 0{\cdot}46 \qquad \frac{k}{e} = 1{\cdot}81$$

It is usual to compare the resistance p with the tensile strength s^1, and to consider the ratio $\frac{s^1}{p}$ as a measure of the ductility of the wire. The quotient is on an average 2·6, but in these experiments it is only 2·16. The Bohemian wire is thus only about 17 per cent. more intractable than softer kinds of wire which have only about one-half its limit of elasticity and specific resistance.

Specifications for the Strength of Iron and Steel.—The largest series of tests on the strength of constructive materials published is that undertaken by Prof. Bauschinger. The number of pieces tested was 874, and included 195 varieties made at different times. The results of these experiments formed the basis for a proposal for the classification of iron and steel by the German Railway Union, which

called forth great opposition in Germany and Austria. F. Fehringer * considers that, as a rule, the demands made in specifications are too high, and are not strictly enforced, and that it would be preferable, instead of giving high minimum limits of strength, to require certain average results from a given number of tests. The current system is unfair to manufacturers on account of the small section of the test-pieces in proportion to that actually used, which makes them very sensitive to trifling irregularities. The regulations of the French Companies are, on the whole, fairer than those of the German and Austrian.

Experiments show that for iron boiler-plates an average ultimate tensile strength of 33 to 34 kilogrammes per square mm. may be expected, with extensions of 20 and 15 per cent., and contractions of 30 and 20 per cent. respectively. In practice, for isolated test-pieces, 10 per cent. less for strength, and 20 per cent. less for extension and contraction, might be allowed as minimum values.

The same principles should be applied to tests for steel, although in the case of this metal the conditions imposed in specifications could generally be more easily fulfilled.

In Austria a system of classification for steel according to hardness has been adopted, which is based upon the amount of carbon in the metal, No. 1 containing 1·5, and No. 7, 0·05 per cent.

Analysis of Tungsten Alloys.—Tungsten steel (*a*) and a tungsten-iron alloy (*b*), made by the Austrian Alpine Mining Company, were analysed at the Vienna Assay Office,† with the following results:—

	Iron.	Tungsten.	Manganese.	Silicon.	Phosphorus.	Carbon.	Total.
(*a*.)	85·00	11·03	1·49	0·26	0·007	2·15	99·93
(*b*.)	68·36	28·18	0·99	0·23	0·008	1·88	99·65

Both products contained traces of sulphur, nickel, and cobalt.

The analysts met with difficulties in the separation of the silica and tungsten oxide, as the methods usually employed were unsatisfactory. The following modified treatment gave good results:—Decompose the well-powdered alloy by aqua regia or by bromine; evaporate on the water-bath with nitric acid; repeat the operation several times; then redissolve in weak nitric acid and filter. The insoluble part consists of all the silica and tungsten oxide, together with a little iron. The latter is separated by fusion with sodium carbonate, and digestion

* *Wochenschrift des österreichischen Ingenieur-und Architecten-Vereins*, vol. viii. p. 311; *Proceedings of Institute of Civil Engineers*, vol. lxxvi. p. 384.

† *Leoben Jahrbuch*, vol, xxxii., p. 39.

in water. On evaporating the alkaline filtrate with nitric acid, all the silica and tungsten oxide are obtained free from iron. To separate the two oxides, it was found best to fuse the mixture with five times its weight of potassium disulphate, and digest with a dilute solution of ammonium carbonate. The silica remains undissolved, and is filtered off and weighed; the tungsten oxide being found by difference.

STATISTICS.

Exports and Imports.—The official returns of the Austrian imports and exports of iron and steel have been recently published.* The total imports of iron and steel into Austria during 1883 were 229,825 metric tons, and the total exports for the same year were 43,151 tons. The more important items were as under:—

	Imports. Tons.	Exports. Tons.
Pig iron	132,492	5,556
Scrap and old iron	48,008	1,954
Iron blooms	1,000	112
Bar iron and steel	8,567	11,924
Rails	5,455	280
Plates and sheets	1,970	4,592
General castings	4,479	2,929
Tubes	7,109	28

* *Archiv für Gesetzgebung und Statistik*, February 1884.

BELGIUM.

The Boring Machine of Dubois and François.—Dubois and François are bringing out a new application of their boring machine. The primary object has been to use it for driving levels in fiery mines, avoiding the use of explosives; but they have now tested it also for ordinary work where there is no objection against firing shots. Professor P. Trasenter, in a paper read before the Liége section of the Association of Engineers on January 13, gave some encouraging details of its work.*

The drill carriage is arranged in such a way that the drill can be moved continuously along a horizontal or vertical line. In soft rock a hole is drilled at each end of a line, and a cut is then made between the two holes down to their entire depth. In hard rock, a series of holes are drilled and the sections between them are taken away by a special bit. As soon as the cut has been made, holes are drilled, and those nearest the cut are fired first. The drill has a 12 c.m. piston, and drills holes 6–8 c.m. in diameter. To make a cut 1·20 by 1·50 metres requires one hour in schist, and less than two hours in sandstone; while the drilling of the necessary holes takes nearly double the time.

The drilling of the cut reduces the number of holes and the quantity of explosives used. It requires only one drill, which needs only the attendance of two or three men, so that the cost of repairs, maintenance, and labour is reduced. Work can be done faster and cheaper with one Dubois and François drill than with four ordinary drills.

Failure of Iron Shaft Tubbing.—An account of the rupture of the cast iron tubbing of a shaft at the Bâneux Colliery, in the province of Liége, has been recently published by P. Banneux in the *Annales*

* *Revue Universelle des Mines*, vol. xiv. p. 694.

*des Travaux Publics de Belgique.** The accident is striking from the fact that none of the universally adopted elements of security were absent.

The tubbing of the Bâneux shaft was required to resist the pressure of 138-feet head of water. It extended from the thill of a coal seam up to a height of 44 metres, the distance to surface being 60·5 metres; and it was composed in height of 72 sections of 0·60 metre each. This length of tubbing of 44 metres was divided into three equal portions, in which the thickness of the metal differed. In the lower portion this thickness was 34 millimetres; in the middle portion it was 30 millimetres; and in the upper portion, 26 millimetres. The shaft was not circular, but four-sided, the sides being unequal and curved, one segment being made to span the whole distance on each side. The segments were bolted together at the angles in the usual manner, the joints being made with strips of lead 0·118 inch thick. On the inside of each segment were three strengthening ribs, each 3·34 inches deep. It is customary to calculate the thickness of such tubbing on the assumption that the shaft is circular, and of a diameter corresponding to the curvature of the segments. Calculated on this basis, the thickness of the lower tubbing should have been, for the larger diameter, 33 millimetres, and for the smaller diameter 30 millimetres. The thickness actually given was 34 millimetres in both cases. The dimensions adopted were not only arrived at in the manner sanctioned by experience and in conformity with the common practice, but, as an additional security, the usual dimensions were slightly exceeded. Thus nothing was wanting to give confidence in the solidity of the structure. Yet this tubbing, calculated, as it was supposed, with a wide margin for safety, to resist a head of water of 42 metres, gave way when the head had reached only 35 metres. The rupture occurred in the middle of the segments, and extended from the bottom to a height of 18 metres through thirty-one successive segments.

The purpose of the author of this report is to show that tubbing of this character is not subjected solely to a stress of compression, as in the case of circular shafts, and that consequently the calculations which are based on that assumption are erroneous and dangerously misleading. He demonstrates that such segments are exposed to a transverse strain by the extremities being forced outward against the pressure which holds the centre in position; that is, the force which is brought to bear upon those pieces tends to cause flexure, and the strain thus

* *Proceedings of the Institute of Civil Engineers*, vol. lxxv. p. 388.

set up increases with the radius of curvature. Such a strain tends to break the segment in the middle, in the manner in which the rupture occurred at Bâneux. The author recommends the adoption of a greater thickness of iron in these cases, and suggests the necessity of taking precautions to counteract the tendency of the angles to yield under the action of the external pressure. In the new tubbing designed for the Bâneux shaft, these suggestions have been acted upon, and the structure is probably the most massive that has yet been constructed.

The Basic Steelworks at Athus.—The new works which are constructed for the daily production of 400 tons of steel by the basic Bessemer process began working regularly at the beginning of the present year. The works are situated at the southern extremity of Belgian Luxemburg; the ore supply being derived from the Grand Duchy of Luxemburg. The two blast furnaces are 62 ft. high, and 20 ft. 4 in. diameter at the boshes, with four tuyeres each. One furnace produces 115 tons of forge pig, and the other 80 tons of foundry pig in twenty-four hours, or the two together 1400 tons a week. Each furnace is provided with five Whitwell stoves, one in reserve, 22 ft. in diameter and 29½ ft. high. The steelworks are on a level 26 ft. lower than the ironworks. A covered way leads from the blast furnace to the converters, and a ladle mounted on wheels brings the liquid metal right on to the converter bridge. The ladle is not made to tip, but is tapped like a cupola, for allowing the metal to flow into the converter after having been weighed. The smaller ladle, that brings the molten spiegeleisen from the cupolas is, however, made to tip. There are two cupolas, each of 2 tons capacity, for melting the spiegeleisen. There are also two 12-ton cupolas for melting the pig iron run when the steelworks may be standing. There are two 10-ton converters, and one in reserve. They are of the ordinary Bessemer form. The blast for the converters is supplied by a blowing-engine of the Cockerill Company's latest type. The metal is received from the converters in a ladle, which is transferred to the casting crane. The ingots are of remarkably smooth surface for extra mild steel, containing 0·09 per cent. of carbon, and from 0·2 to 0·3 per cent. of manganese. There are 280 hands employed at the blast furnaces and steelworks.*

* *Iron*, vol. xxiv. p. 10.

Production of Coal.—According to Prof. P. Trasenster of Liége,* the production of coal in Belgium during 1883 was 18,135,000 metric tons, against an output of 17,591,000 tons in 1882, and 16,873,000 tons in 1881. The quantity of coal imported was 1,314,000 tons, while the exports amounted to 5,855,000 tons. The consumption was 13,594,000 tons.

Pig Iron.—The production of pig iron during 1883 was 770,000 tons, against a total of 727,000 produced in the previous year. The pig iron produced in 1883 included 565,000 tons of forge iron, 144,000 tons of Bessemer and basic pig, and 61,000 tons of foundry iron.

Wrought Iron.—The production of wrought iron during 1883 was 478,000 tons against 500,000 tons in the previous year, and 479,000 tons in 1881.

Steel.—The quantity of Bessemer steel ingots produced in 1883 was 178,000 tons. The quantity of rolled steel was 153,000 tons.

Imports and Exports.—The Belgium imports and exports of iron and steel during 1883 were as follows: †—

	Imports.	Exports.
	Tons.	Tons.
Steel:—		
Crude steel	54	699
Rails	1,229	80,094
Bars, plates, and wires . . .	5,440	7,652
Manufactured steel	907	1,944
Pig iron	173,136	12,743
Scrap iron	15,029	8,060
Hammered, drawn, and rolled iron:—		
Wire	5,676	3,004
Rails	690	9,576
Plates	881	48,153
Other descriptions	6,612	215,813
Forgings:—		
Nails	320	7,784
Other descriptions	2,920	25,809
Castings	3,059	15,297
Totals . .	215,953	436,628

* *Revue Universelle des Mines*, vol. xv. p. 291.
† *Iron*, vol. xxiii. p. 385.

CANADA.

Canadian Coals.—Dr. J. M. Dawson has recently published * some useful notes on the coals and lignites of North-West Canada. These mineral fuels are all of Cretaceous and Tertiary age. Where the Cretaceous rocks have been much disturbed and folded, the coal passes into the anthracite. Out on the plains the strata are nearly flat, and as they recede from the mountains the coals show a larger percentage of water, and assume the character of lignites.

The Iron Ore Deposits of Central Canada.—In a series of articles on this subject which recently appeared in *The Canadian Mining Review*,† it is stated that the Silurian limestone covers the southern part of the country, resting unconformably upon Laurentian rocks. The geological features are described in detail, and it is evident that the iron ore was originally deposited in open cavities, and was subsequently buried under a mass of material. The series of upheavals has brought ore to the surface in positions which simulate the form of metallic veins, but which are evidently beds of remarkable extent. The ore is an exceedingly pure variety of magnetite.

Various mines are described, and the following are some analyses of the ore :—

	Emma Mine.	Baker Mine.	Coe Hill Mine.
Ferrous oxide	28·32	29·18	26·12
Ferric ,,	63·24	64·95	65·20
Chromic ,,	trace	none	none
Phosphorus	trace (0 to 0·051)	trace (0 to 0·088)	0·02
Sulphur	0·02	0·13 (0 to 0·13)	0·07
Silicious rock-matter	8·36	5·66	8·48
	99·94	99·92	99·89

* *Nature*, vol. xxx. p. 154.

† 1884, vol. ii. No. 1.

Coal and Iron Ore in Nova Scotia.—The total sales of coal in Nova Scotia * during the year 1883 amounted to 1,297,523 tons, while the amount of coal raised was 1,422,553 tons, being an increase of 56,000 tons over the production of 1882. The number of miners employed was 4635 in twenty-three collieries. The iron ore raised was 52,410 tons, an increase of 10,000 tons over the previous year, and the quantity of coke made was 44,189 tons. The Nova Scotia iron ore is said to be of excellent quality, and the opinion is expressed that the iron-mining industry has a great future before it.

* *Report of the Department of Mines, Nova Scotia*, for 1883.

CUBA.

Iron Ore in Cuba.—Large deposits of iron ore have been discovered in Cuba, the extent of which will cause the island to take rank with other countries as a source of supply of the raw material for iron-making. An American mining engineer states that he is familiar with most of the rich fields in the United States and in Europe, but that he has never seen any like those of Cuba. He adds that he has seen veins of iron ore, but that there are on the surface immense deposits varying in thickness from 10 to 50 yards, mostly in blocks of 2 to 20 tons weight. At one place he found, by actual measurement, that there must be present about 1,837,450,000 cubic yards of ore. This deposit is situated only about half a mile from the sea, where a good harbour can be opened to ship the ore. Further in the interior there is another large deposit.*

* *Iron*, vol. xxiii. p. 333.

FRANCE.

Spontaneous Combustion of Coal.—M. Fayol concludes from his experiments, reported in the *Comptes Rendus de la Société de l'Industrie Minérale*, that the rise of temperature accompanying the absorption of atmospheric oxygen by finely powdered coal is the chief cause of its spontaneous combustion. He finds that only a low temperature is needed to ignite powdered coal; lignite igniting at 150° C., and anthracite at 300° C., and the ordinary varieties of coal at intermediate temperatures. The avidity with which the oxygen is absorbed increases with the rise of temperature, which finally becomes sufficiently high for ignition.

An important part in spontaneous combustion has been ascribed by many authorities to finely divided pyrites. The author, however, on subjecting this mineral to the same experimental conditions as the coal specimens, found a less energetic action of the atmosphere. When gradually heated up to 200° C., pyrites and coal behaved exactly alike till a temperature of 135° C. was reached; from this point the temperature of the pyrites remained the same, while the coal powder rapidly became hotter till the igniting point was reached.

Analyses of Fuels.—Boussingault gives an account * of the examination of a variety of combustible minerals, including bitumens, lignites, fossil resins, coals, and anthracites, from various localities. The results of the analyses are given in the following table :—

* *Annales de Chimie et de Physique*, vol. xxix. pp. 363-392.

	C.	H.	O.	N.
Liquid bitumen of Bechelbronn	87·50	11·10	0·30	1·10
Bitumen of Bocanémé	88·52	11·36	...	0·12
Liquid bitumen of Schwabweiler	85·38	12·33	2·17	0·12
Bitumen of Magdalena	88·31	9·64	1·68	0·37
Liquid bitumen, Alsace	87·40	12·60	...	...
Bitumen of Orinoco	77·93	7·94	13·87	0·26
Black naphtha of Balakhany	85·42	6·66	7·76	0·16
Bitumen of Bastennes	85·74	9·58	2·88	1·80
Bitumen of Pont-du-Château	77·52	9·58	10·53	2·37
Bitumen of Abruzzi	81·83	8·28	8·83	1·06
Bitumen of Chinese fire-wells (filtered)	86·82	13·16	...	0·02
,, ,, ,, (squeezed out)	82·85	13·09	4·06	...
Bitumen of Judæa	77·84	8·92	11·53	1·71
Asphalt of Coxitambo, Peru	87·75	9·68	2·58	...
Asphalt of Oran, Algeria	73·47	10·48	15·49	0·56
Asphalt of Egypt	85·29	8·24	6·22	0·25
Mineral wax of Baku, Russia	84·33	13·71	1·96	...
Fossil resin of Bucaramanga	82·70	10·80	6·50	...
Fossil resin of Santa-Rosa, Antioquia	77·80	9·60	12·57	0·03
Fossil resin of El Retiro, Antioquia	71·89	6·51	21·57	0·03
Copaline of Highgate	85·68	11·47	2·85	0·06
Copaline of India	85·73	11·50	2·77	...
Guayaquilite resin, Ecuador	77·66	8·20	14·80	...
Retinasphalt of Bovey-Tracy	74·12	8·18	17·51	0·19
Elaterite of Australia	72·15	10·30	16·84	0·71
Elaterite of Wallachia	69·70	10·19	19·40	0·71
Jonite of California	67·55	7·13	25·05	0·27
Torbanite of Scotland	82·30	10·50	5·00	2·20
Dysodil of Roth	69·01	10·04	19·25	1·70
Dysodil of Sicily	57·73	9·35	31·91	1·01
Lignite of Chile	79·24	5·50	13·69	1·57
Lignite of Antioquia	66·81	4·48	27·27	0 98
Bituminous lignite of Elboyen	77·04	7·81	12·65	1·86
Jet of Spain	81·98	5·81	11·53	0·68
Fibrous coal of Antioquia	87·05	5·00	6·56	1·39
Coal of Canoas, Bogota	80·96	5·13	12·50	1·41
Cannel coal of Montrambert	82·33	3·52	12·52	1·63
Fossil charcoal of Montrambert	93·05	3·35	3·43	0·17
Coal of Montrambert	86·67	4·56	7.98	0·79
Fossil charcoal of Blanzy	87·81	3·88	7·67	0·64
Anthracite of La Mure, Isère	95·26	2·51	1·56	0·67
Spheroidal anthracite	91·51	3·87	3·36	1·26
Anthracite of Borneo	93·66	2·94	2·88	0·52
Anthracite of Chile	92·25	2·27	4·94	0·56
Anthracite of Pembrokeshire	95·34	2·42	1·35	0·89
Anthracite of Muso	94·83	1·27	3·16	0·74
Adamantine anthracite	97·60	0·70	1·70	...
Graphite of Korsöh	97·87	0·37	1·70	0·06

Pyrometers.—An exhaustive article on this subject has recently been published in the *Portefeuille Economique des Machines.** Among the more recent forms of pyrometers may be mentioned the following :—

Tremeschini's Pyrometer.—This is based in principle on the expansion of a thin plate of platinum, which is heated by radiation from a mass

* Translated in the *Iron and Coal Trades' Review*, vol. xxviii. p. 693.

of metal previously exposed to the temperature of the atmosphere or medium to be measured. The instrument is simple in its action, not cumbrous, and very easy to manage. It has given satisfactory results when recently employed, and its indications appear to be correct, at any rate up to 800° C.

Trampler Pyrometer.—This pyrometer is based upon the difference in the coefficients of dilatation in iron and graphite. The instrument is composed of an iron tube, in which is placed a hard but very porous stick of graphite. On exposing the tube to heat it lengthens much more than the graphite stick. By an ingenious arrangement the relative dilatation is largely magnified. These pyrometers have been used with success, and are very convenient for following the variations of temperature within a furnace where the pyrometer can be fixed.

Ducomet Pyrometer.—A series of alloys, the melting temperature of which varies in a given manner according to the proportion of the metals which compose them, may, as is well known, be used to establish a scale of temperature. This is the principle of the Ducomet pyrometer. This pyrometer does not allow the variations of temperature within a furnace to be followed, but it has been found useful and satisfactory for indicating clearly the moment when a particular temperature is attained.

Saintignon Pyrometer.—This pyrometer is based on the elevation of temperature in a current of water circulating through a tube placed in the hot atmosphere, the temperature of which has to be ascertained.

Amagat Pyrometer.—This pyrometer was invented in 1882 by M. Amagat, Professor at Lyons. It also is based on the circulation of water, but differs from the preceding in the fact that instead of passing through a casing, the water passes along a double worm plunged into the heated atmosphere. Having first passed round a thermometer, it descends by one branch of this worm and rises by the other. Its temperature is again measured at the exit, and the difference between the two thermometers determines the temperature of the worm.

Boulier Pyrometer.—This instrument, patented in 1883 by Messrs. Boulier Brothers, is based upon the same principle as the two last mentioned. The water circulates in a casing of thin copper. The pipes which carry on the circulation are both placed in the cooling vessel, through which there is a rapid circulation of cold water. Two thermometers indicate the temperature of the water, first at its exit from the casing, and secondly at its exit from the refrigerator; the difference between the two determining the temperature of the casing. In order to

prevent the serious accidents which might occur in case the casing were to burst, and a quantity of water were to be discharged into a furnace at high temperature, the instrument is fitted with an electric stop-valve. This is formed of a small balance, which remains in equilibrium so long as the current of water flows steadily, but which, in case of any irregularity, closes the pipe leading from the reservoir to the casing, and at the same time rings a bell. According to a report made by M. Lauth, manager of the manufactory at Sévres, in January 1884, this instrument indicates very rapidly and very faithfully any rise or fall of temperature at the point where it is placed.

The three instruments last described are based on a true scientific principle, but it will be seen that they are not very portable, and as they require a reservoir of water, can scarcely serve for any purpose except that of following the variations of temperature in the same furnace. They must also be fitted with means to ensure the regular flow of a considerable quantity of water throughout the time of their working.

Improved Method of Casting.—A patent has recently been granted for an improved method of casting railway carriage and truck wheels, and other objects in iron, copper, or steel, by which the use of the ordinary core-boxes is obviated, and a considerable saving of time effected. In the case of railway carriage and truck wheels, the mould is formed by building upon a horizontal frame, first, a portion of the central hub, and a portion of the lugs to receive the iron spokes, which may be cast in if desired; and, secondly, the other parts which, when fixed to a sand-box or frame, and rammed with sand, present the required shape of wheel mould in sand when the parts forming the metal pattern are withdrawn from the mould. The outside of the mould is chilled by a suitably constructed chilling-piece. For vertically raising from the sand mould the various metallic parts of which the pattern is composed without shaking or injuring the sand mould, a special form of lifting appliance is used, which consists of a threstle or yoke-shaped bracket or stand, fitted with a vertically sliding cylinder or bar, held in position by a spring.

The Distinction between Steel and Iron.—M. Evrard has recently given * an account of investigations made at Firminy on the subject of a practical way of distinguishing between iron and steel.

* *Mémoires de la Société des Ingénieurs Civils*, 1884, p. 252.

.ccording to the definition of steel generally adopted at the present me, the word must be applied to all those welded products which ın be hardened, and to all varieties of malleable ingot metal whether ıey can be hardened or not.

The absence or presence of welds will, therefore, decide whether a roduct which cannot be hardened is steel or wrought iron, and the fect of etching a flattened and smoothed surface with nitric acid was ıund to give decisive evidence on this point.

Steel of the second kind will always present a uniform dull grey ppearance, the acid attacking it equally over the whole surface. Vrought iron is acted on irregularly; a roughly-grooved surface is roduced, on which longitudinal stripes, some formed of bright grains, thers of the dull grain of etched steel, are developed. In iron looms the stripes are broader and interrupted, the bright grains are ıore plentiful, and the cinder becomes visible in the form of black ands. In wrought iron which has been formed by the welding ›gether and further diminishing of different layers of metal, the nes of contact become clearly visible, the different layers forming ıroughout separate bands.

The following experiment proves that the bright grains are actually roduced in the welding. A number of extra-soft steel bars were piled nd welded in the same manner as is usual with wrought iron. Although the welding was not perfect at every point, no traces of imperect places were visible after polishing. On treatment with acid, every eld became visible as a line of brilliant grains standing out from the enerally dull-grey surface. These lines of bright grains are, therefore, n infallible proof that a material which cannot be hardened is wrought on, while their entire absence characterises it as steel.

The author's definition of steel does not appear to be so generally ccepted as he and a large section of French manufacturers desire. The warm discussions which have lately been carried on in French echnical journals on the question whether mild ingot metal has to e classified as steel or as iron have been called forth by the difference in the duties on imported iron and steel (6 francs on the former nd 9 francs on the latter), and the distinguishing test adopted by the ustoms authorities. The latter adhere to their old-established view hat the capability of being hardened is the essential characteristic f steel, and exact for those important products of modern processes, he different varieties of soft ingot metal, only the lower impost. French iron and steel manufacturers, as represented chiefly by the

"Comité des Forges de France," have been urging on the administration of customs that these new products, usually called "acier doux" (mild steel), but also "fer fondu" (ingot iron), should be classed as steel, the characteristic property of which they consider to be its much higher tensile strength as compared with iron. The administration in consequence invited the opinion on this point of the Consulting Committee of Arts and Manufactures, who commissioned the eminent metallurgist Professor Lan of the School of Mines to report on the subject. Professor Lan in his conclusions entirely coincided with the French ironmasters' view that the metal in question is steel, on account of its mode of manufacture, its chemical composition, and its industrial applications; and at the same time indicated tests which might readily be applied for the purpose of identification by the customs officials. Notwithstanding, however, the high and incontestable authority of their reporter, the Consulting Committee have not become sufficiently convinced by his arguments to make the desired change in the duty.

Method of Distinguishing Iron and Steel.—M. Walraud* describes an easy method for distinguishing iron from steel when in small pieces.

The test-piece, which may be some 25 or 30 cm. long, is slightly indented 4 or 5 cm. from each of its ends; one of the ends is then heated gradually to a dull-red heat, and is afterwards very slowly cooled in water, the metal being scratched repeatedly with a file until the clean surface takes a dull yellow colour, or, better still, becomes blue. It is then plunged into the water, and the cooling is completed rapidly. Both ends of the piece are then broken off, and serve for comparison.

Ordinary wrought iron appears fibrous or granular, but if treated as above its fracture is dull, and it has a short fibrous structure. Hard and moderately hard steel is finely granular, but after treating in the manner described above, the fracture is bright and partially or entirely smooth. Swedish iron shows only traces of a fibrous structure, and does not otherwise differ from soft steel, but when it has undergone the treatment described its fibres are more apparent, and the smooth appearance has disappeared, while in the case of soft steel it is all the more obvious.

* *Mémoires de la Société des Ingénieurs Civils*, 1883, p. 531.

Classification of Steels.—In the classification of steels according to their hardness, the descending scale from hard to soft varieties has been generally adopted in France, the example having been set by the Creusot Works; and some steelworks, notably the "Société des Forges et Aciéries du Nord et de l'Est," at Trith-Saint-Léger, near Valenciennes, have increased the numbers of their grades from eight to ten, so as to allow of the classification of extra-soft basic metal. The following is the scale which is adopted: *—

No.	Percentage of Carbon.	Tenacity in Kilogrammes per sq. mm.	Elongation per Cent.	Description.	Remarks.
1	0·65—0·80	80–105	4½	Extra hard	Tempers extra well
2	0·50—0·65	75—80	9—12	Very hard	Tempers very well
3	0·45—0·50	70—75	12—15	Hard	Tempers well
4	0·35—0·45	65—70	15—18	Hard	Tempers
5	0·30—0·35	60—65	18—20	Semi-hard	Tempers
6	0·25—0·30	55—60	20—22	Soft	Tempers but little
7	0·20—0·25	50—55	22—24	Soft	Does not temper
8	0·15—0·20	45—50	24—26	Very soft	Does not temper
9	0·10—0·15	40—45	26—28	Extra soft	Does not temper
10	0·05—0·10	35—40	28—32	Extra soft	Does not temper

The test-pieces are round, 100 mm. long and 16 mm. in diameter.

The following is the classification which is used at the Longwy Works for their basic steels:—

No.	Tenacity in Kilogrammes per sq. mm.	Elongation per Cent.	Description.	Remarks.
1	70—75	12—15	Hard	Tempers well
2	65—70	15—18	Hard	Tempers
3	60—65	18—20	Semi-hard	Tempers fairly well
4	55—60	20—22	Semi-hard	Tempers but little
5	50—55	22—24	Soft	Tempers but little
6	45—50	24—26	Soft	Does not temper
7	40—45	26—28	Very soft	Does not temper
8	35—40	28—30	Extra soft	Does not temper

Resistance of Steel Rails to Fracture.†—M. Coüard, chief inspector of the Paris-Lyon-Méditerranée Railway Company, draws

* *Le Fer*, January 15, 1884.

† *Revue Générale des Chemins de Fer*, 1883, No. 5.

the following conclusions from the statistics of the Company for the years 1868 to 1880 :—

The superiority of steel rails over iron is mainly due to the smaller amount of injury received by the former than by the latter before the head is worn out. The injuries, however, are very important on account of the long time which a steel rail lasts.

In 1868 the Company had a single line of a length of 106 kilometres, and in 1880 one of 5782 kilometres, steel rails being used. Up to this latter year it had only been necessary to replace per annum, for injury done to the rail, 1·2 rails in every 1000, their average age being 5·2 years.

Of all the injuries to which steel rails are exposed, fracture is the most important, as it endangers safety. In no case, however, could an accident entailing leaving the metals be traced to the fracture of a Vignol steel rail, but a large number were caused by the breaking of double-headed rails.

The author considers the question of the influence of the atmospheric temperature on the fracturing of rails, and represents graphically the fractures which occurred with different temperatures during the period including the years 1876 and 1880, from which it is immediately evident that the number increases as the temperature diminishes. He also believes that it is on the tension produced in the rail by the atmospheric temperature, and not on the varying resistance of the ground on which the sleepers rest, that the fracturing of the rail depends, and he draws attention to certain cases in Russia in which cast iron columns had split simply from the fact that one side was exposed to the sun while the other was covered with snow.

Since 1875, 1510 rails had broken within their guaranteed period, the way the fracture occurred being shown by the following table :—

Fractured across	64 per cent.
,, lengthwise	17 ,,
,, at the bolt-holes	7 ,,
,, at the fastening holes in the base of the rail	12 ,,

The author draws attention to the small number of fractures which occurred at the bolt-holes, and states that the rails used on the Company's line have these holes drilled. He compares the percentage with that occurring at the same point in the rails used by the Silesian railways, which have these holes formed by punching, the percentage in this latter case being stated to be as much as 74.

In various tables are represented the resistance to mechanical tests of rails delivered by different works, and the results obtained from their employment. The author states that of all the different varieties used, those made from the hardest steel proved to be the best as regards liability to fracture.

Detection and Estimation of Zinc and Lead in Iron Ores.—A. Deros * has recently proposed the following electrolytical method of estimating zinc and lead in iron ores. It possesses the advantages of requiring but little manipulation, and is cheap and exact. In order to detect the presence of zinc, the hydrochloric acid solution of one gramme of the ore is poured gradually, without agitation, into an excess of ammonia. When cold the mixture is electrolysed in a platinum crucible, which acts as the positive electrode; a platinum spatula or coiled platinum wire acting as negative electrode. The current should be strong enough to give 300 to 400 c.c. of detonating gas per hour. The liquid must be kept ammoniacal. After three or four hours the platinum spatula is withdrawn, washed, and then treated with a few drops of dilute sulphuric acid to dissolve the greyish deposit. The solution is evaporated to dryness with addition of a few drops of cobalt solution, and strongly heated. A green residue shows the presence of zinc. The colouration is very distinct, even when 0·0005 gramme of zinc is present in 1 gramme of the ore.

In order to estimate the zinc, the solution of 1 gramme of the ore is treated as above described, the negative electrode consisting of a sheet of platinum 3 cm. broad and 5 cm. long. After twelve hours the zinc will be completely precipitated. The platinum sheet is carefully washed by dipping it in water, and is then immersed in a solution of potash or soda, which dissolves only the zinc. The alkaline solution is again electrolysed, and the deposit washed successively with distilled water, alcohol, and ether, and dried at 100°. It is advisable to wash with water before interrupting the current. The results are very exact.

In order to estimate the lead in iron ores, 1 gramme of the finely powdered ore is placed in a conical flask with 3 or 4 grammes of cadmium, and gently warmed with hydrochloric acid. When the solution is complete, and no gas given off from the cadmium, all the lead is precipitated. The liquid is carefully decanted off and the residue washed. Five or six c.c. of nitric acid are then added, and the

* *Comptes Rendus*, vol. xcvii. p. 1068.

solution of cadmium and lead transferred to a crucible which acts as the negative electrode, the positive electrode being a platinum cone. In four or five hours the lead is completely precipitated in the form of peroxide on the positive electrode, which is washed, dried, and weighed. The weight obtained multiplied by 0·866 gives the exact weight of lead.

This simple and rapid process may also be applied for the qualitative detection of lead, and is very sharp, as the brown colour of the lead peroxide may be very clearly distinguished from the shining surface of the platinum.

The Influence of Copper in Rolling Steel.—Choubley in the *Bulletin de la Société de l'Industrie Minérale* * confirms the observations made by Wasum (this Journal, 1882, p. 369) on the influence that copper in steel exercises on its rolling qualities. He finds that even one per cent. of copper, in the absence of sulphur, does not produce red-shortness. He melted 15 kilogrammes of scrap steel with 150 grammes of copper; the metal produced giving on analysis the following results:—

Carbon	0·495 per cent.
Manganese	0·460 ,,
Silicon	0·150 ,,
Phosphorus	0·069 ,,
Sulphur	0·040 ,,
Copper	0·960 ,,

This steel did not show the slightest trace of red-shortness.

As Wasum's experiments were made with steel low in phosphorus, the author made some additional experiments to determine the influence of copper on steel containing phosphorus. At the Firminy Steel-works copper was added in the metallic state to the melted pig, the composition of the resulting steel being as follows:—

No.	Carbon.	Manganese.	Phosphorus.	Sulphur.	Copper.	Silicon.
1	0·510	0·454	0·192	0·068	0·360	From
2	0·600	0·539	0·204	0·045	0·370	0·10
3	0·492	0·360	0·150	0·073	0·420	to
4	0·580	0·393	0·174	0·054	0·440	0·15
5	0·540	0·427	0·192	0·070	0·480	

None of the samples showed the slightest trace of red-shortness, and they could all be rolled perfectly well.

* Vol. xiii. p. 205.

STATISTICS.

Iron Ore.—According to the official statistics recently issued,* the total production of iron ore in France during the year 1882 amounted to 3,467,251 metric tons, valued at £673,677. Iron ore is mined in thirty-five of the departments; Meurthe-et-Moselle alone furnishing 62 per cent. of the total production. The following departments contributed quantities over 100,000 tons :—

Department.	Production.
Meurthe-et-Moselle	2,160,000 tons.
Ardèche	206,000 ,,
Haute-Marne	194,000 ,,
Pyrénées Orientales	146,000 ,,
Saône-et-Loire	146,000 ,,
Cher	109,000 ,,
Gard	108,000 ,,

The importation of iron ore amounted to 1,426,000 tons, and the exportation to 121,000 tons. Eighty-two iron mines were working, giving employment to 6500 miners.

Pig Iron.—The production of pig iron in France during 1882 was 2,039,067 tons. 210 blast furnaces were in blast; 148 using coke, 43 charcoal, and 19 mixed fuel. The manufacture of pig iron necessitated the combustion of 2,528,000 tons of coke, 67,000 tons of coal, and 80,000 tons of charcoal.

Wrought Iron.—The production of wrought iron was 1,073,021 tons. There were 997 puddling furnaces and 146 refining hearths without counting the reheating furnaces.

Steel.—The production of steel amounted to 458,238 tons. Of this quantity 273,400 tons were Bessemer steel and 159,500 tons Siemens-Martin steel. There were 56 steelworks in activity, with 29 converters, 62 Martin furnaces, 56 puddling or refining furnaces, 35 cementation furnaces, and 142 crucible steel furnaces.

Coal.—The production of coal in France during 1882 was 20,603,704 tons, representing a value of £10,184,900. 308 collieries were working; they employed 77,800 workmen underground and 30,500 at the sur-

* *Statistique de l'Industrie Minérale pour l'Année* 1882.

face, making a total of 108,300. The deepest shaft is that of Montchanin in the department of Saône-et-Loire; it has attained a depth of 2156 feet.

Statistics for 1883.—According to the report of Prof. P. Trasenster * of Liége, the production of coal in France during the year 1883 was 21,466,000 tons. The imports were 11,071,000 tons, the exports 680,000 tons, and the total consumption 31,837,000 tons. 2,067,000 tons of pig iron were produced, 968,000 tons of wrought iron, and 509,000 tons of steel. Of the latter quantity 329,000 tons were Bessemer steel and 155,000 tons Siemens-Martin steel.

Production of Steel Rails.—The following are the quantities of steel rails which were made to order for the last five years, together with their realised values: †—

	Quantity in Metric Tons.	Value in Francs.	Mean Price Delivered per Ton.	Mean Price at Works per Ton.
1879	117,080	27,356,142	233·65	209·32
1880	683,636	135,332,600	197·96	188·30
1881	871,953	161,762,600	206·87	195·91
1882	286,073	60,591,570	211·90	198·45
1883	78,888	13,385,600	170·00	166·00

* *Revue Universelle des Mines*, vol. xv. p. 288.
† *Le Génie Civil*, vol. v. p. 9.

GERMANY.

CONTENTS.

I.—*ORES AND FUEL.*

The Condition of the Iron Mines in Siegen.*—At the meeting of the Institute of German iron-metallurgists held at Düsseldorf on the 15th of June last, G. Weyland read a paper on the condition of the Siegen iron mines. He stated that iron ores occurred very abundantly throughout Siegen; spathic ore with 33 to 40 per cent. of iron and from 5 to 7 per cent. of manganese being the most important. This, when calcined, gives from 45 to 50 per cent. of iron, and from 7 to 10 per cent. of manganese. It is occasionally found changed into brown hæmatite containing 45 to 50 per cent. iron, and 3 to 6 per cent. manganese. Specular iron ore, with 45 to 60 per cent. iron and 2 to 4 per cent. manganese, occurs in some of the lodes, and is very probably also an alteration product of spathic ore. In the Lower Devonian the iron ore only occurs in veins. In the district of the Dill and the Lahn, in the so-called Coblenz beds, it occurs as bedded deposits.

Fear has been expressed that the increased quantity of ore which has been raised of late years might have seriously diminished the resources of Siegen. This is, however, very improbable. As showing the large extent of the deposits of iron ore in Siegen above the valley level, it may be stated that twenty-five years ago the iron ore was mined in Siegen entirely by means of adits, and that so far back as the year 1444 there were twenty-nine ironworks at work, since which

* *Stahl und Eisen*, vol. iv. p. 405.

period the output has been almost uninterrupted. A vertical height above valley level of, at the utmost, 200 yards may be accepted as representing the height of the ore deposit; of this, five to ten yards are annually removed. The depth of the mines in Siegen is, however, by no means great, and, from a miner's point of view, there is nothing to prevent the mines reaching a depth of 1000 yards, or even more. There are at present no signs of falling off in the richness of the lodes, and all appearances point to the hypothesis that the principal fissures were formed by plutonic agency, in which case it is most probable that the lodes have a very great depth.

There will be no difficulty in increasing the output very considerably, and it is not the failure of ore which Siegen has to fear, but rather the depression in value. The enormous import of foreign ore in 1883 was the cause of a diminished output of Siegen ore. Spanish iron ore containing 54 to 56 per cent. of iron sold on June 15th for fifteen marks per metric ton, at which price it was impossible for even the best situated Siegen mines to compete, as the cost of raising the spathic ore is from 7 to 10 marks per ton, and every ton of roasted spathic carbonate costs the mine 10 to 13·5 marks per ton, and it does not seem probable that these prices can be materially reduced.

The most important question for the Siegen mines is, to find a market for a larger output of ore, but, unfortunately, there is not a market even for the present output.

Electro-Magnetic Ore Dressing.—The Friedrichssegen Mine, at Oberlahnstein, produces iron ore and zinc-blende, ores difficult to separate as their specific gravity is nearly the same. Two classes of ore are mined: cobbing ore and smalls. The portion of the cobbing ore that is rejected in sorting, goes to the electro-magnetic separators, while the smalls are dressed in the usual manner. Middlings containing blende and iron ore are obtained in this dressing, and they also go to the electro-magnetic plant.

The ore to be treated is prepared for the subsequent process by roasting; the iron ore being thus converted into magnetic oxide. The picked lump ore is roasted in a shaft-kiln with coke dust. The consumption of fuel is slight on account of the sulphur in the blende not being greater than 110 lbs. to 8 tons of ore, which are daily put through one furnace. The furnace requires the labour of two men. The roasted ore is reduced to 5 mm. grain by a stone-breaker and a pair of rolls, and then passes to the electro-magnets. The fine middlings are worked

in a reverbatory furnace, having a capacity of 20 tons in twenty-four hours. After being roasted, the ore is spread out on a cooling floor, and finally put through a screen with 4 mm. mesh, the fine material passing to the electro-magnets, and the coarse being crushed by a small pair of rolls. The dressing is done by sixteen electro-magnetic separators arranged in sets of four, in pairs above one another. The upper pair receives the ore from the shoots, and partially separates the blende from the iron ore. The products, which are worked over once more in the lower apparatus, consist of a mixture of blende and quartz, iron ore, blende middlings, and iron ore middlings. The middlings are treated over again. As there is a good deal of dust in working, all the apparatus are connected with an exhaust fan. The electro current is generated by dynamos; one machine requiring a motive power of one horse-power being sufficient to supply four generators. With two sets of four apparatus, 24 tons of ore can be treated for each set in twelve hours, yielding a product of 7 tons of roasted blende and 18 tons of iron ore. The iron ore is sold as such, while the zinc ore is worked further by screening.*

Relative Value of Wet and Dry Coal.—Some interesting experiments have recently been made for the purpose of determining the respective values of wet and dry coal for the evaporation of water. The results showed that small coal containing 18 per cent. of water and 9·9 per cent. of coal dust evaporated 5·7 lbs. of water per lb. of fuel, while the same amount of coal containing 3 per cent. of water evaporated 8 to 8·5 lbs. of water per lb. of fuel. The figures showed that the employment of wet coal gave rise to a loss of from 15 to 25 per cent.

New Coke Oven.—A new coke oven has been patented by H. Stier of Zwickau, in which, in case of interruption of the operation, some coke shafts may be thrown out, and each separate coke shaft used as a generator. The coke shafts are surrounded by the heating shafts so as to isolate the former. The coke shafts have an opening at the top and another at the bottom, and the heating shafts are provided with openings in their walls through which the heating gases may pass. Generators are placed on the outside of the plant, and enclose between them a channel which carries off the products of combustion. The heating gases passing through the generator are mixed with air

* *Engineering and Mining Journal*, vol. xxxviii. p. 21.

enter the heating chambers, and finally escape through proper funnels. The vapours and products of distillation developed in the coke chambers pass into a condenser, while the lighter, non-condensible gases pass into a main gas channel, from whence they may again be utilised for heating the coke chamber.

Collection of the By-Products from Coke Ovens.—At the meeting of the Society of German iron-metallurgists held on June 15, Dr. Otto read a paper * on the working results of the Hoffmann coke oven, which has been been patented in Germany, England, and elsewhere, and consists mainly in a combination of Siemens regenerators with any ordinary coke oven, an arrangement being also attached to permit of the collection of the products of distillation.

During the past year twenty of these ovens have been in work at the Pluto Colliery near Wanne, and at the Silesian Coal and Coke Works at Gottesberg. The results of the working have been so exceedingly satisfactory, that there are already 120 such ovens in course of construction in Germany. At the Pluto Works the ovens are of the ordinary horizontal type, 9 metres long, 600 mm. internal diameter, and 1600 mm. internal height. The original ovens were arranged in such a manner as to cause the products of distillation to circulate and be burnt around and beneath the coking chamber. With the Hoffmann attachment, the openings connecting the side chambers with the coking one are closed, and the products of distillation escape through the openings in the roof of the oven, and pass through a system of condensers and scrubbers, where the tar and ammoniacal liquor are collected. The gas escaping is pumped into a tube which is forked at the end. The gas can, in this manner, be introduced beneath either end of the bed of the oven, where it is burnt by hot air entering from a regenerative chamber previously heated by the escaping products of combustion. There are two such regenerators, one at each end of a system of ovens, the products of the combustion of the gas, and the air for the combustion, passing through them in turn, the periodical change of direction being made in the usual way. The incoming air is heated by this means to a temperature of 1000° C., so that the amount of gas required to be burnt in order to keep up the coking is very small, the result being that at the Pluto Works there is as much as 100 c.m. of gas per oven in excess daily over that required for combustion under the oven. The temperature attained

* *Stahl und Eisen*, vol. iv. p. 396.

is so high that the coking of the normal charge of 115 cwts. of dry coal only requires forty-eight hours, or even less. By burning more or less of the gas the time may be lengthened or shortened as desired. The quality of the coke is exceptionally good.

The yield of coke at the Pluto Works from ovens arranged on Hoffmann's system for the collection of the tar and ammonia is 7 per cent. higher than in the case of the ordinary ovens, the yield from dry coal being 75·56 and 67·7 per cent. respectively. Pyrometric observations showed the temperature in the combustion chamber to be from 1200° to 1400° C.; in the side chambers, 1100° to 1200° C.; in the regenerator at the moment of introducing the cold air, 1000° C.; and at the end of this period, 720° C. The escaping gases in the flue have a temperature of 420° C. The distillation products on escaping from the coking chamber have a temperature of 600° to 700° C., which is reduced after passing through the condensers to from 17° to 30°. In these condensers about 75 per cent. of the total amount of ammoniacal liquor is collected, the remainder being obtained by passing the gases through vertical cylinders, divided into sections by perforated plates, through which a continual spray of water passes. The temperature of the gas after passing the scrubbers is reduced as low as 13° C.

The tar is allowed to separate in cisterns from the ammoniacal liquor, which, if not rich enough in ammonia, may be used over and over again in the scrubbers until the desired richness is attained; this is about 3° to 3½° Beaumé, or containing 1·777 per cent. ammonia. At the Pluto Works the ammonia is not converted into sulphate, but the liquor is sold as ammonia.

The yield of sulphate of ammonia would be about 1 per cent. of the dry coal, and the tar obtained varied from 3·46 per cent. to 2·78 per cent. of the dry coal, these being the results of the best and the worst month's working respectively, the difference being due to the fact that for a considerable period there was an insufficient supply of water for cooling purposes, the quantity required being 5 cubic metres daily for each oven.

The analysis of the tar showed it to contain

Benzine	0·954 to 1·06 per cent.
Naphthaline	4·27 ,, 5·27 ,,
Anthracene	0·574 ,, 0·64 ,,
Pitch	about 50 ,,

The residue (carbon) insoluble in concentrated acetic acid is about 10 to 25 per cent. of the tar.

The composition of the gas will be seen from the following analysis, that of the gas supplied for lighting purposes by the Cologne Gasworks being appended for the sake of comparison :—

	Volume. per Cent.	Dry.	Cologne Gas.
Benzine vapour	0·60	0·61	1·54
Æthylene	1·61	1·63	1·19
Sulphuretted hydrogen	0·42	0·43	...
Carbonic anhydride	1·39	1·41	0·87
Carbonic oxide	6·41	6·49	5·40
Hydrogen	52·69	53·32	55·00
Methylene	35·67	36·11	36·00
Water	1·21	0·00	...
	100·00	100·00	100·00

The coke-oven gas has about one-half the illuminating power of the Cologne gas. It might, however, be burnt by using larger burners, or could be used for generating steam, for which purpose the excess of heat of the escaping waste gases, which have, as before stated, a temperature of 420°, might also be employed.

The Coalfield of Saarbrücken.—R. Nasse has recently written an elaborate monograph on the coal measures of Saarbrücken,* which, together with the accompanying geological maps and sections, gives a very clear insight into the structure of the coalfield.

Towards the north the coal formation rests unconformably on the Devonian Hunsrück schists, while on the west and south it is overlain by Bunter sandstone, and on the east by Tertiary beds. According to recent geological studies, only a relatively small portion of the district belongs to the coal measures; the larger portion, which contains several narrow coal seams, belongs to the Permian. The coal measures are divided into two groups :—

1. Lower or Saarbrücken beds, 2671 metres thick in the western portion, containing 341 coal seams with 138·18 metres of coal. Only 64 of the seams with 63·24 metres of coal are, however, workable. In the eastern portion the beds are 1667 metres thick, and contain 233 coal seams with 126·38 metres of coal. Of these seams, 73 with 79·82 metres of coal are workable.

2. Upper or Ottweiler beds, 1850 to 3600 metres thick, containing only 7·5 metres of coal in various seams.

* *Zeitschr. Berg. Hütten. Salinenw.*, vol. xxxii. pp. 1–89.

According to the author's estimate, the seams existing in the Prussian district to a depth of 1000 metres contain 3000 million tons of workable coal, after deducting 25 per cent. for waste and loss in working. As the output from the Saarbrücken collieries during the financial year 1882–83 amounted to 5,600,000 tons, the amount of coal available would last, at this rate, for 536 years. An annual increase must, however, be expected. Assuming the annual increase in the consumption to be 150,000 tons, the estimated available quantity would be only sufficient to last for 166 years.

The Poetsch System of Mining in Quicksand.—This system of freezing quicksand preliminary to sinking through it (*vide* this Journal, 1883, p. 826), has been tried on a large scale at the Max Colliery, Michalkowitz, Upper Silesia;* but owing to a series of breakdowns, the period for the completion of the work passed, and it had to be stopped.

This method has also been applied at Siemens and Halske's lignite mine at Schenkendorf.† In sinking the shaft, a bed of quicksand was struck at a depth of 70 feet, and it proved impossible to continue the work by piling. The shaft, 15 feet square, was, by Poetsch's method, sunk though the 110 feet bed of quicksand. With 16 freezing pipes it took 33 days to complete the ice-wall, and in a comparatively short time the shaft was excavated.

A fourth work is now progressing at the Emilie Mine, near Finsterwalda,‡ where a bed of quicksand 132 feet thick is to be passed through with a 12-foot circular shaft, using 12 freezing pipes.

Winding Apparatus for Mines.—A winding apparatus has been patented by A. Lindenberg of Dortmund. The improvement has for its object to prevent the weight of the counterbalance rope or chain from acting upon the winding rope. For this purpose each end of the counterbalance rope is connected with a separate thin suspension rope, which passes over a guide-pulley, and is thence connected with the opposite cage. In this way a portion of the weight of each cage is balanced by the opposite counterbalance rope, and as the cage is lowered, the length and weight of such rope will be proportionately increased.

* *Berg- und Hüttenw. Zeitung*, 1884, pp. 93 and 169.
† *Ibid.*, 1884, p. 123.
‡ *Engineering and Mining Journal*, vol. xxxviii., p. 458.

Basic Refractory Materials.—Two years ago the Berlin Society of Arts offered a prize for the best essay on the properties of basic refractory materials. The prize has now been awarded to A. Wasum of Bochum, whose paper has recently been published in the Transactions of the Society.*

The comparative experiments were carried out on the following plan: —Bricks of 100 mm. long, 75 mm. wide, and 50 mm. thick were, after being dried, placed on their broadest side for five days in the kiln ordinarily used for burning basic bricks. After cooling the bricks were measured. One portion of each was kept in dry air in order that its durability might be observed, another portion was heated to redness, then cooled with water, and kept in dry air until it disintegrated; a third portion was also cooled, when red-hot, in water, then again heated to redness, and kept in dry air until it disintegrated.

The highest degree of fusibility was accompanied by such a deformation that an accurate measurement was not possible.

The crude materials used had the following composition:—

	Dolomite.	Magnesite.	Limestone.	Clay.	Magnesia.
Lime	31·62	1·69	55·33	...	
Magnesia	20·19	44·98	...	...	
Silica	1·70	0·13	...	49·40	
Alumina	0·09	0·84	1·07 (silica, alumina, ferric oxide, manganese oxide)	38·98 (alumina, ferric oxide)	Magnesite burnt at a white heat.
Ferric oxide	1·22	1·63			
Manganese oxide	trace	0·29		...	
Carbonic anhydride	45·35	50·57	43·47	...	
Loss by ignition	...	...	...	11·50	
	100·17	100·13	99·87	99·88	

Seventy-one experiments were made in order to test the action of clay, silica, phosphoric anhydride, ferrous oxide, ferric oxide, manganic oxide, and basic converter cinder. The latter had the following composition—

Silica.	Lime.	Magnesia.	Phosphoric Anhydride.	Ferrous Oxide.	Ferric Oxide.
8·14	48·25	4·65	15·85	9·48	6·14

In the case of dolomite, the investigation embraced experiments on the action of ferrous oxide, ferrous phosphate, ferric phosphate, clay, silica, manganic oxide, and basic converter slag.

The author draws from his experiments the following conclusions:—

* *Verhandlungen des Vereins für Beförderung des Gewerbfleisses*, 1884, p. 104; *Engineering and Mining Journal*, vol. xxxvii. p. 332.

Good bricks may be made of dolomite, limestone, and of magnesia burnt at a white heat, without the addition of any binding material. This is, however, not the case with magnesite, which, when ground, is not sufficiently plastic. Much finer bricks are obtained when clay is added. Even magnesite yields faultless bricks under these conditions. The addition of clay may be made to the extent of 5 per cent. without perceptibly impairing their quality. The bricks should be burnt at the highest white heat and for a considerable time.

Dolomite and lime bricks, made without any binding material, will last about three weeks in dry air. By the addition of clay their durability is much increased. Bricks made of magnesia, with or without clay, last more than three months. The temperature at which the bricks have been burned greatly influences their durability. Bricks placed in the cooler parts of the kiln are consequently of inferior quality. It is important, therefore, in constructing the kilns to have the flues so arranged that the temperature is uniform throughout the kiln.

Dolomite and lime bricks, cooled with water when red-hot rapidly disintegrate. The disintegrating process is, however, much retarded by the addition of clay. When the bricks, after cooling with water, are reheated to redness, it takes them a few days longer to disintegrate. Cooling with water has no effect on magnesia and magnesite bricks. Some that were experimented on had not begun to crumble after having been kept a year and three months. By cooling with water when red-hot, all basic bricks crack more or less; but these cracks are rarely so large that they fall to pieces at once. When, however, disintegration sets in, the bricks split in the direction of the cracks.

Dolomite, lime, and magnesite bricks shrink about 24 per cent. when exposed to the highest white heat. Magnesia bricks shrink only 4 per cent. All substances that tend to decrease the refractory character of the bricks increase their shrinkage.

Magnesia bricks have a much greater power of resisting the action of cinder formed in metallurgical processes than dolomite and lime bricks. The oxides of iron are the worst enemies of basic brick, and care should, therefore, be taken to select raw material as free as possible from iron. Silica, phosphoric anhydride, and manganese oxides are not so destructive to basic bricks.

Undoubtedly the best material for basic bricks is magnesia, preheated at the highest white heat. Bricks of this material are remark-

ably durable either in dry or moist air. They resist the action of cinder at high temperatures and exhibit a small amount of shrinkage.

The great practical drawbacks of the lime and dolomite bricks is, that they disintegrate in so short a time, so that it is impossible to manufacture a stock of them. The heavy shrinkage too, leads to the production of irregularly shaped bricks, which cause large joints in the masonry, leading to its rapid destruction. With the magnesia brick all these drawbacks disappear. Their cost, however, is so great that their employment could only come into question if their duration in metallurgical use surpassed that of the lime and dolomite bricks three or four times. This, however, is not the case, the author having found by experiments on a large scale that they do not resist the action of slags much better than lime and dolomite bricks.

II.—*BLAST FURNACE PRACTICE.*

The Behaviour of Phosphorus in the Blast Furnace.*—While in the making of Bessemer iron the whole of the phosphorus in the charge is practically found in the resulting metal, a different behaviour of this substance has been observed in the smelting of highly phosphoric ores. An important investigation on the relative quantities of phosphorus in pig iron and the slag accompanying it, on the conditions which influence the reduction of phosphorus and some of its associates, as well as a searching examination of the furnace gases for phosphorus, has recently been carried out by G. Hilgenstock at the Hoerde furnaces. The results may be summarised as follows:—

1. No appreciable quantities of phosphorus are carried off by the gases.

2. Under certain conditions a portion of the phosphorus is found in the slag in the form of phosphoric acid. The quantity is comparatively higher at a lower furnace temperature and with a charge containing more phosphorus. In agreement with this rule, barely a trace of phosphoric acid is found in the slag obtained in the smelting of Bessemer pig.

3. The richer a pig iron is in phosphorus, the less silicon and carbon it contains; the presence of phosphorus does not, however, seem to diminish the power of pig iron to alloy with these bodies. The author

* *Stahl und Eisen*, vol. iv. p. 2.

found that metal containing 15·5 per cent. phosphorus readily alloyed with either an equal part of ferro-silicon with 9 per cent. silicon, or of ferromanganese with 5·7 per cent. carbon, the product in both cases being of the average composition of its respective components.

4. With a highly phosphoric ore the slag contains so much more phosphoric acid as its percentage of silica decreases.

5. The active agent, direct or indirect, in the reduction of phosphorus is essentially carbon.

As regards the distribution of phosphorus between metal and slag, the author gives the following series of results of experiments made upon charges with varying amounts of phosphorus :—

	Pig Iron.				Slag.
No.	Si.	P.	Mn.	C.	P.
1	trace	5·96	0·92	0·88	2·57
2	trace	7·20	0·36	1·11	2·39
3	0·02	6·24	0·51	0·95	1·74
4	0·06	6·07	0·75	1·19	1·22
5	0·09	4·57	1·98	0·90	0·38
6	0·28	3·61	1·69	1·19	0·18
7	0·28	3·79	1·13	1·12	0·19

This shows that the phosphorus in the slag increases with that in the ore. The results of a further series of twenty-three analyses show that the relative proportions of carbon, silicon, and phosphorus in the pig iron may vary between the following limits :—

Phosphorus.	Silicon.	Carbon.
3·26	1·03	2·01
12·12	0·02	0·87

And under these conditions, as the phosphorus increases, the silicon and carbon in the metal diminish.

The relation between silica and phosphoric acid in the slags is demonstrated by twelve analyses, ranging from 34·58 per cent. silica with 6·00 phosphoric anhydride, to 38·75 silica accompanied by 1·26 phosphoric anhydride; the sum of the two bodies is throughout approximately constant.

The most highly phosphorised metal which has come under the author's notice contained 25·65 per cent. The higher the amount of phosphorus the weaker the metal becomes; its structure is crystalline with needle-shaped aggregations of crystals like ferromanganese. The

magnetic properties showed no perceptible decrease at 9·6 per cent. Metal with 16 per cent. is only feebly attracted by the magnet, and with 25·6 per cent. the attraction is scarcely perceptible.

Highly phosphorised metal offers some difficulties in the analysis, as it dissolves but slowly in acids, and resists the action of copper-ammonium chloride and of iodine and cold water. Carbon could only be estimated by volatilising the iron and phosphorus in a current of chlorine and burning the residue in oxygen.

Washing Blast Furnace Gases.—In discussions of the advantages and means of frequently purifying blast-furnace gases, the view is advanced that a direct contact with cold water must, in all cases, be accompanied by a great loss in heating power, as, in addition to the loss of their sensible heat, the gases will be diluted by the introduction of moisture which will lower the temperature of combustion. The amount of this loss is in no case of great consequence, if only the cooling is carried far enough. If as low a temperature as 15° C. is attained, the moisture which it is possible for the gas to hold is not more than 1·05 per cent., or not more than is present in the driest gases; as a consequence, moist furnace gases—those discharged from certain furnaces in which moist brown ores are smelted, containing up to 12 per cent. of steam—will be freed from the greater part of their water. It is calculated * that a blast-furnace gas with 12 per cent. moisture and of an initial temperature of 200° C. has the same temperature of combustion (1470° C.) whether it is burnt hot or after cooling down to 15° C. If the initial temperature was less than 200° C. but above 100°, the products of its combustion would even be lower if it is burnt hot than if it is burnt after cooling. Naturally the loss in heat units cannot be avoided, but would amount in the case under discussion only to about 5 per cent. Things will, however, be essentially different if the cooling is imperfect; the higher the temperature of the gases in contact with cooling water is allowed to remain, the more steam will be retained by them. At 70° C. they absorb about 15 per cent. of their weight, and even very moist gases would take up still more water while losing not so much less of their heat as in the case of a perfect refrigeration. The inevitable result would be a lowering of the temperature of combustion, and increased loss of heat by waste chimney gases.

Whenever it is decided to purify blast furnace gases, either for the

* *Stahl und Eisen*, vol. iii. No. xi.

purpose of fitting them for use in fire-brick stoves or of recovering any of their constituents, the great advantage of direct mixture with cold water as a means of purification, and its harmlessness to the heating power of the gas, if it is only carried out thoroughly, should not be lost sight of.

Occurrence of Ferrate and Manganate of Potassium in the Blast Furnace.—B. Platz * describes the discovery, during the destruction of an old blast furnace, of some masses of solidified slag, which, though quite dry when taken out of the furnace, proved to be hygroscopic. This was found to be due to the presence of crystals of potassium ferrate and potassium manganate disseminated through the slag. The quantity of potassium ferrate which was present amounted to several kilogrammes. It was chiefly in the slag masses found near the boshes, and its formation was probably due to the fact that the masses formed were protected from the action of the descending charge by a thick layer of coke, and that the ascending gases being unable to penetrate the solid or pasty mass, ferrate of potassium was formed by the action of ferric oxide on the large amount of potassium carbonate present in the slag.

The following are the results of analyses of portions of the slag which originally contained potassium ferrate:—

	I.	II.
Ferric oxide	13·72	7·83
Ferrous oxide	24·75	12·77
Manganous oxide	0·46	0·92
Lime	33·02	59·62
Magnesia	1·27	1·41
Calcium sulphide	1·35	1·37
Alumina	6·72	3·10
Silica	11·98	6·64
Totals	93·27	93·66

The remainder consisted of the alkalies, chiefly as sulphates and carbonates. Well-developed crystals of anhydrous potassium sulphate were also present in the slag.

* *Stahl und Eisen*, vol. iv. p. 262.

III.—*MANUFACTURE OF IRON AND STEEL.*

Use of Liquid Carbonic Anhydride in Steel Manufacture.*— This is employed with the intention of producing an equal and high pressure upon the surface of the fluid steel, so as to produce a casting fairly free from blowholes. A steel collar is placed upon the projecting rim of a mould, and on this is fixed a vessel containing about 80 kilogrammes of carbonic anhydride. By this means a pressure of 75 atmospheres may be exerted on the steel, and the pressure is retained until the metal is solid throughout, for which result a period of several hours is necessary. A very dense casting is produced, and a saving is effected of about 30 per cent. in the weight of the lost dead-head.

Tempered Cast Steel.—The manufacture of this substance has spread from Belgium into Westphalia and the Rhine Provinces. It is made from old steel and scrap steel, which is cut into small pieces and smelted with coke in a cupola, and then run into slightly dried sand moulds as in the case of ordinary cast iron. The castings are tempered by packing them in powdered red hæmatite in boxes made of refractory material, and heating in a tempering furnace. This operation imparts to the metal such a degree of strength and tenacity as to render it superior to ordinary cast steel; but the greatest advantage it possesses over malleable cast iron and cast steel is its cheapness. Frequently, however, it is much less free from blowholes than is malleable cast iron, but this defect has been lately, to a certain extent, overcome, and the metal is much used for trolley wheels in the Westphalian and Belgian coal-mines. The manufacture of tempered steel offers no special difficulties, and any foundry can make it with a small outlay for cupola and tempering furnaces.†

On the Burning of Iron and Steel.—Professor Ledebur in a paper on this subject ‡ states that iron that has been raised nearly to its temperature of fusion and slowly cooled is designated as "burned" or overheated metal. It is both red-short and cold-short, and exhibits a coarse crystalline structure, and a bright glistening fracture. Such iron contains oxygen; but this oxygen is not, as is commonly believed, derived from without during the heating, but was previously con-

* *Zeitschrift des Vereins deutscher Ingenieure*, vol. xxviii. p. 401.

† *Deutsche Industrie Zeitung.*

‡ *Freiberg Jahrbuch*, 1883, p. 19; *Proceedings of the Institute of Civil Engineers*, vol. lxxv. p. 396.

tained in the iron itself in the form of scale or slag. When the iron is raised to the fusing heat, a chemical reaction takes place; the metallic iron reduces the sesquioxide to protoxide, which, by being dissolved in the iron, alters the properties of the latter. The coarsely crystalline quality of iron so treated is not due solely to the presence of the oxygen. The metal usually contains phosphorus, which is well known to give a coarse grain accompanied by the quality described as cold-short. The crystallisation takes place during the slow cooling while at rest. The greater the proportion of phosphorus present, the lower is the temperature to which the iron may be raised without being burned. Pure iron should not take up more than 0·25 per cent. of oxygen in solution. This substance does not greatly affect the ductility of the metal when cold; it, however, acts like sulphur on its malleabillity.

The qualities of steel also undergo change when heated to a high temperature, or when subjected to a lower temperature for too long a time. The richer the steel is in carbon, the lower is the temperature at which the change takes place. Therefore, the harder the steel, the more carefully it is to be dealt with in the fire. Such overheated steel becomes cold-short, and if the temperature be increased, showers of sparks are thrown off, and the steel is said to be "burned." The alteration brought about in this way has generally been attributed to a diminution in the proportion of the carbon though this assumption is not warranted by the results of analysis. The presence of manganese and silicon is of more weighty consequence. When steel containing these is heated, it is not the carbon but the manganese and silicon that first become oxidised, and there results an important change in the properties of the steel. Later, the carbon is oxidised; and while the carbonic oxide escapes, the manganese and silicon oxides remain behind, and the whole molecular structure of the metal is altered. If the heating be carried still further, the iron will next be oxidised. A cast iron furnace door, exposed for several years to the flame of a coal-fire, was found to contain 27·8 per cent. of oxygen, in combination with iron, sulphur, nickel, copper, phosphorus, and arsenic. The cause of the sparks is not the combustion of the carbon, and the consequent generation of carbonic oxide, but the escape of gases imprisoned in the steel. Similar results may be brought about by exposing the steel to a lower temperature for a longer time; the oxidation of the constituents will, in this case, be effected in the order mentioned above, the only difference being in the slower action. Steel

altered in this way is well described as "dead." A regeneration of the metal by mechanical treatment is hardly possible, since the original chemical composition cannot be restored by such means.

Utilisation of Slags from the Basic Bessemer Process.—The average slags produced by the basic Bessemer process in German works contain about 18 per cent. of phosphoric anhydride, 8 per cent. of silica, and 50 per cent. of lime. The recovery of the phosphoric acid has hitherto been prevented by the silica and ferric oxide in the slags. With the use of too much, or too concentrated, hydrochloric acid in the decomposition, metallic oxides are dissolved and the silica is coagulated. Prof. C. Scheibler * has modified the process by the use of properly diluted acid, which removes the phosphates and silicates in solution, the metallic oxides being dissolved to a very slight extent. From the solution the phosphoric acid may be precipitated as basic phosphate of lime, a valuable fertiliser. The insoluble residue, which is poor in silica, contains sufficient iron and manganese to be of use in the blast furnace.

The slag is first calcined, and the product heated with steam to slake any caustic lime present. The powdered material is then screened to separate shots of iron and undecomposed lumps of slag. The free lime is then removed, as milk of lime, by washing with water. The washed residue is heated with very dilute hydrochloric acid, one part acid to ten parts water. The amount of acid required varies with the composition of the slags, and more particularly with the amount of free lime. The clear solution is treated with milk of lime, which precipitates both phosphate and silicate of lime together, or, if the neutralisation be only partial, the phosphate is precipitated, and the bulk of the silica remains in solution. The precipitate is washed and dried, and is either sold as biphosphate of lime, or is converted into superphosphate by treatment with sulphuric acid.

The present development of the basic Bessemer process is such as to provide sufficient slag to furnish 20,000 tons of phosphoric acid annually. One ton of slag requires 20 to 30 cwts. of hydrochloric acid, and yields about 10 cwts. of phosphate. Factories for working this process have been established at Schalke and Stolberg.

Utilisation of Tin Plate Scrap.—In a paper read before the Society of German Engineers,† Dr. L. Czimatis records the various

* *Zeitschrift des Vereins deutscher Ingenieure*, vol. xxviii. p. 206.

† *Ibid.*, p. 225.

attempts which have been made to utilise tin plate scrap. A method has recently been patented, in which the tin scrap is placed in a rotating cylinder provided with a steam-jacket, and treated with caustic soda and oxide of lead. The metallic lead precipitated oxidises, and is used over again; while the solution is either boiled down for sodium stannate or treated with carbonic acid to precipitate the tin oxide, which is then reduced in a reverberatory furnace. The value of the iron remaining has hitherto been much impaired by the presence of small quantities of tin, as iron containing 1 per cent. of tin is cold-short; with 0·1 per cent. the quality is much better. The above process gives iron with but 0·038 per cent. of tin, a quantity which does not affect the mechanical properties of the iron.

IV.—*PHYSICAL PROPERTIES OF IRON AND STEEL.*

Testing Sheet Iron by the Determination of its Tensile Strength.—A. Schuchert relates * some instances in which material was most unjustly condemned by the buyer's examiner on the ground of low tensile strength, and draws attention to the frequency of such annoying occurrences. He believes that the causes for such discrepancies in the results obtained by different operators is due to the employment of testing machines of antiquated types; to the improper form and careless preparation of the test-piece; to the experiments being carried out in different manners; and to the operators not requiring the plates to undergo really similar tests. In order to prevent disagreeable conflicts between seller and buyer, all sheets should, as far as is possible, be made to stand similar tests; that there should be a complete agreement in the way in which the test is carried out; and that only machines of proved value should be employed.

He points out that if a bar breaks near one of its ends, it cannot have the same elongation as it would were it to break in the centre; as in the former case, the elongation would mainly take place on one side of the place of rupture, whereas in the latter case both sides would have more or less extended equally; and he proposes that no test should be accepted unless the bar has broken fairly in the centre. As regards the form of the test-pieces, the author says that at the present time it varies according to the particular taste of the individual who examines it, although it is of great influence on the result of the test. He compares the different main forms of test-pieces, and believes that the most

* *Stahl und Eisen*, vol. iv. p. 137.

trustworthy, when accurately made, is that one in which the ends are broader than the central part, and which have a hole bored through them for the insertion of a pin. The author also expresses the opinion that every testing machine should be supplied with some reliable arrangement for determining its accuracy.

The Best Length for Steel Rails.—In a recent article on this subject,* the following table is given respecting the steel rails usually employed in the several countries named :—

Countries.	Length of Rail.	Weight of Rail per Metre.	Total Weight of Rail.
	Metres.	Kilogrammes.	Kilogrammes.
Germany . . .	6·6 7·22 7·5 9·0	31·36—36·38	207—300·6
England . . .	6·4 (21 feet) 7·315 (24 feet) 8·534 (28 feet) 9·144 (30 feet)	38·7—43·17	248—389
France . . .	5·5 8·0 (usual) 11·0	30·0—38·40	210—414
Belgium . . .	9·0	35·2—38·0	317—342
Holland . . .	7·0	30·5—38·6	214—270
Austro-Hungary .	6·5 7·0 8·0 9·0	30·5—38·0	214—279
Italy . . .	9·0 12·0	27·0—36·5	243—438
Spain . . .	6·2 8·0 9·0	30·0—36·0	180—324
Russia . . .	7·36 8·53	26·86	197—228
United States . .	9·14	?	?

The author, in comparing these rails with one another, divides them into two classes—long and short—and sums up the advantages possessed by the long rails over their short competitors as follows :—

The cost of laying down a new railroad diminishes as the amount of material used for connecting the rails at the joints decreases. In Germany the cost of one of these connections using four bolts with spring rings is about 3s. 6d. to 3s. 9d., consequently for both ends of the rail it amounts to 7s. or 7s. 6d.; and if the length of the rail be increased from 6 to 9 metres, a saving is effected of 417 shillings per kilometre, or 2·3 per cent. of the cost of the material of the permanent way.

* *Stahl und Eisen*, vol. iv. p. 263.

Both in straight lines and in curves the regularity of direction increases with the length of the rails. The longer rail has the firmer bed, and consequently the cost of keeping the road in order is diminished. The wear and tear of the rolling-stock is less and the motion is steadier.

As to the maximum length which may be given to rails, the author is of opinion that wrought iron rails should not exceed 7 metres; while for cast steel they might be made as long as 10 or 12 metres; but 9 metres is the best general length.

Long Steel Rails.—With a view to lessen the noise caused by the trains crossing the railway bridges in Hanover, due to the violent vibrations of the rail-joints, the original rails have been taken up and steel ones 88 feet 6 inches long laid down in their place. The new rails were manufactured at the Osnabrück Steelworks, and the result of the innovation is in every way satisfactory.

V.—*ANALYSIS OF IRON AND STEEL, &c.*

The Estimation of Manganese.—The very great importance of manganese for the manufacture of steel renders it absolutely necessary that there should be some method by which the percentage present in its alloys with iron and carbon may be accurately determined. Numerous methods have, in consequence, been proposed at one time or another, but have never become generally employed.

The difficulty in the correct estimation of manganese increases with an increase in its percentage in the alloy; but the necessity for its being correctly determined increases in a similar degree, as the price of the alloy does not rise in arithmetical proportion with each successive addition of manganese, but in a geometrical proportion; the alloy becoming more and more difficult to prepare the richer it is in manganese.

Of all the methods which have been proposed, Professor Ledebur * considered those which were best adapted for comparison to be the methods of Volhard, Pattinson, and Hampe.

A careful estimation of the manganese in a ferromanganese was first made by the ordinary method of analysis:—1 gramme was dissolved in nitric acid, evaporated to dryness with the addition of some ammonium nitrate, heated till acid fumes ceased to escape, dissolved in hydrochloric acid, diluted with water to one-third of a litre, a large quantity of ammonium chloride added, over neutralised with ammonium carbonate, 1 c.c. of acetic acid added and boiled. The precipitate was washed with boiling

* *Chemiker Zeitung*, vol. viii. pp. 910, 927, 963.

water containing some ammonium chloride, dissolved in hydrochloric acid, and reprecipitated and washed. The small amount of iron present in the two filtrates was precipitated by the addition of a few drops of ammonia to the boiling solution, and the precipitate was re-dissolved and re-precipitated. The ammoniacal filtrates containing all the manganese, copper, cobalt, and nickel were acidulated with acetic acid, and the last three metals precipitated by sulphuretted hydrogen. Finally, the manganese was precipitated by ammonia and ammonium sulphide, with prolonged boiling; the precipitate was filtered and heated with sulphur in a current of hydrogen and weighed as sulphide. The ferromanganese proved to contain 46·22 per cent. of manganese, and the analysis took two days to complete.

The manganese was next determined by Volhard's method, the operations being as follows:—1 gramme was dissolved in nitric acid evaporated as in the ordinary method; heated; the residue dissolved in hydrochloric acid; evaporated to dryness with the addition of sulphuric acid; heated on a sand-bath till all the hydrochloric acid had volatilised and sulphuric-acid fumes began to appear; cooled; dissolved in water; placed in a litre flask; neutralised with sodium carbonate till the red colour appeared; the iron precipitated by zinc oxide; diluted to one litre; allowed to settle; filtered, and 200 c.c. of the filtrate (= 0·2 grammes ferromanganese) were used for each assay. The solution taken for the assay was acidulated with two drops of nitric acid, boiled and titrated with permanganate solution, the known iron standard of which multiplied by 0·2946 gives the manganese standard. The time required was ten hours, and the following were the percentages of manganese obtained:—

I.	II.	Mean.
46·21	46·33	46·27

An assay was next made by Hampe's process, the operations pursued being the following:—0·3 gramme of the ferromanganese was dissolved in a 400 c.c. beaker with 25 c.c. of nitric acid, specific gravity, 1·18; boiled gently; 5 grammes potassium chlorate added little by little; heated to a temperature approaching its boiling-point for two hours; diluted with hot water; filtered on asbestos; washed until free from chlorine, testing the filtrate, acidulated with sulphuric acid, with iodine and starch, and the manganese estimated by the reduction of the dioxide by a definite quantity of a solution of ferrous sulphate of known standard, and estimation of the ferrous oxide in excess. The following were the percentages of manganese obtained:—

I.	II.	III.	Mean.
46·49	46·64	45·94	46·35

Several other assays gave the percentage of manganese 0·5 to 1 lower,

and this proved to be due to the fact that it had not been entirely precipitated. The time taken for the three assays was ten hours, of which at least five were needed to wash the precipitated manganese free from potassium chlorate, which is exceedingly difficult to remove; Hampe himself states that two hours are required for this operation. Thus, as far as rapidity is concerned, Hampe's method is not better than Volhard's, and it seems scarcely to be so trustworthy.

In estimating the manganese by Pattinson's method, 0·3 gramme of the ferromanganese was dissolved in 9 c.c. nitro-hydrochloric acid in a 400 c.c. beaker; evaporated to drive off the excess of acid (but not to dryness). The residue was dissolved in 5 or 6 c.c. of cold water, neutralised with calcium carbonate until the solution became brown, and the iron began to be precipitated; 50 c.c. of a solution of chloride of lime (produced by treating 15 grammes with 1 litre water and then filtering) were added, and the whole was heated to about 80° C. by the addition of 300 c.c. of boiling water. The iron and manganese were then precipitated by calcium carbonate in slight excess. If the solution becomes red through the formation of permanganic acid, boiling with a little alcohol suffices for its reduction. The precipitate was next filtered on a paper filter washed till free from chlorine, dissolved on the manganese estimated by ferrous sulphate and permanganate, as in Hampe's method. The time required was five and a half hours.

The following were the percentages of manganese obtained:—

I.	II.
46·28	46·28

Thus it is evident that for the purposes of the laboratories of metallurgical works Pattinson's method is by far the best. If copper, cobalt, or nickel is present in the metal, the results would show too great an amount of manganese, but the errors due to this source are scarcely of much importance, as copper is very rarely present in ferromanganese in a quantity exceeding 0·4 per cent., which would only cause an error of 0·17 per cent.; and cobalt and nickel taken together are rarely present in iron or ferromanganese in quantities exceeding 0·05 per cent., which would only produce an error of 0·02 per cent.

The Estimation of the Carbon in Iron by Combustion in Oxygen.—In determining the total amount of carbon in iron by dissolving the metal in a solution of the double chloride of copper and ammonium, filtering the residue on asbestos, and then transferring the asbestos and precipitate to a boat and burning in a current of oxygen, it is impossible to prevent a slight loss of the precipitate during the transference to the boat. To obviate this, several kinds of apparatus have

been proposed, and Professor C. Balling gives the following comparative results obtained—(1) by the ordinary method, and (2) by filtering the residue on to asbestos contained in a platinum tube and burning it *in situ*: *—

	I. Per Cent.	II. Per Cent.
Grey pig iron	3·000	3·027
,, ,,	3·434	3·461
White ,,	3·017	3·091 3·040
,, ,,	3·203	3·247

Analysis of Basic Bessemer Slag.—The following is a mean analysis of the basic slags which are produced in the different German works: †—

Silica	6·20
Carbonic anhydride	1·70
Sulphur	0·56
Phosphoric anhydride	19·53
Iron	9·70
Manganese	9·50
Lime	47·60
Alumina	2·58

No slag produced in the German basic works contains less than 15 per cent. of phosphoric anhydride, and frequently the quantity present is as much as 20 per cent.

Crystals in Slag from the Basic Process.—A. von Groddeck and K. Broockman ‡ have recently observed brown rectangular thin tabular crystals in cavities in the slags from the basic process at Peine. These crystals probably belong to the rhombic system. They are transparent, and have a glossy lustre and a hardness of 3·5. Minute blue rhombic crystals also occur. The analyses gave the following results:—

	Brown Crystals.	Blue Crystals.
Lime	58·01	55
Magnesia	0·88	...
Manganese oxide	...	3
Ferrous oxide	2·93	6
Phosphoric anhydride	38·75	35

This composition indicates that the crystals consist of tetra-basic calcium phosphate, and are, therefore, identical with those obtained by Hilgenstock (this Journal, 1883, p. 838) from the Hörde slags.

* *Chemiker Zeitung*, vol. viii. p. 821.
† *Le Génie Civil*, vol. v. p. 40.
‡ *Stahl und Eisen*, vol. iv. p. 141.

Gas Inclusions in Iron and Steel.—F. C. G. Müller has published at some length * the results of further investigations into the nature of the gas inclusions in iron and steel.

The first point to be determined was the nature of the gases occurring in the blowholes in rising steel, and with this end in view analyses were made.

Soft Basic Steel produced with $2\frac{1}{2}$ per cent. of ferromanganese (35 per cent. Mn), disturbed, scattering, and moderately rising, with many radial blowholes, gave 36 per cent. of gas, which consisted of:—Carbonic oxide, 0·6 per cent.; hydrogen, 85·4; nitrogen, 14·3; total, 100·3.

Basic Metal, finished without any addition, quiet in the ladle and in the mould, scattered little and rose slowly; the ingot contained but a few radial blowholes, and gave 20 per cent. of gas of the following composition:—Carbonic oxide, 0·0 per cent.; hydrogen, 64·5; nitrogen, 35·4; total, 99·9.

Basic Steel, produced with the addition of 5 per cent. ferrosilicon (14 per cent. Si), and $2\frac{1}{2}$ per cent. ferromanganese (70 per cent. Mn), rose quietly, and gave a moderately porous ingot, with 22 per cent. of gas, which contained:—Carbonic oxide, 0·4 per cent.; hydrogen, 86·4; nitrogen, 12·7; total, 99·5.

Basic Steel, produced with 5 per cent. ferrosilicon (14 per cent. Si), rose quietly, and yielded an ingot with only a few radial blowholes, and gave 6 per cent. of gas, containing:—Carbonic oxide, 0·0 per cent.; hydrogen, 54·7; nitrogen, 45·3; total, 100·00.

The steels which were used for these last two experiments, notwithstanding the large quantities of ferromanganese and ferrosilicon used in their formation, contained only traces of silicon, and but 0·4 per cent. of manganese.

The percentage of nitrogen in the gases appears to increase with the decrease in the absolute quantity of gas.

The author remarks, that after these results there is no further need for additional experiments to prove that the phenomenon of rising is due to an occlusion of hydrogen and nitrogen in the steel or iron.

With regard to the nature of the gases escaping from iron and steel when in a fluid condition, samples were collected by filling up the mould with sand directly after pouring, and covering it over with a plate having but one small opening for the gas to escape through. The small quantity of free oxygen present in the gas was undoubtedly derived from residual air in the mould, and this, together with four times its amount of nitrogen, was subtracted in order to give the true analysis. The following results were obtained:—*Pig Iron.*—Graphite, 3·104 per cent.; "combined" carbon,

* *Stahl und Eisen*, vol. iv. p. 69.

0·584; silicon, 1·68; manganese, 1·93. *Gas.*—Carbonic oxide, 37·3 per cent.; hydrogen, 58·3; nitrogen, 0·5; carbonic anhydride, 3·9; total, 100.

Spiegeleisen.—Carbon, 4·180 per cent.; manganese, 7·37; silicon, 0·253. *Gas.*—Carbonic oxide, 48·7 per cent.; hydrogen, 49·5; nitrogen, 0·5; carbonic anhydride, 1·3; total, 100·00.

Phosphoric Pig Iron.—Carbon, 3·099 per cent.; manganese, 0·736; silicon, 0·203; phosphorus, 3·025. *Gas.*—Carbonic oxide, 39·6; hydrogen, 46·8; nitrogen, 10·0; carbonic anhydride, 3·6. The ingot was free from blow-holes, and developed less gas than ordinary Bessemer pig or spiegeleisen.

The author concludes from the results of his own analysis, and of those which have been made by others, that carbonic oxide has a tendency to escape before solidification of the metal; this combination of oxygen being without the property possessed by hydrogen and nitrogen, of alloying with the metal.

Bessemer Rail Steel.—Carbon, 0·23 to 0·28 per cent.; silicon, 0·15 to 0·25; manganese, 0·5 to 0·6; phosphorus, 0·06 to 0·08. *Gas.*—Carbonic oxide, 37·3 per cent.; hydrogen, 47·3; nitrogen, 7·9; carbonic anhydride, 7·5.

Bessemer Spring Steel.—Carbon, 0·48 to 0·53 per cent.; silicon, 0·15 to 0·25; manganese, 0·8 to 0·9; phosphorus, 0·06 to 0·08. *Gas.*—I. Carbonic oxide, 34·0 per cent.; hydrogen, 49·5; nitrogen, 8·6; carbonic anhydride, 7·9. II. Carbonic oxide, 45·9; hydrogen, 41·4; nitrogen, 9·9; carbonic anhydride, 2·8. A number of other analyses are also given which relate to Bessemer metal.

Basic Bessemer ingot-iron containing: carbon, 0·05 to 0·1 per cent.; silicon, trace; manganese, 0·45 to 0·55; phosphorus, 0·05 to 0·1; gave gas of the following mean percentage composition as deduced from several analyses:—Carbonic oxide, 65 per cent.; hydrogen, 5; nitrogen, 30; carbonic anhydride, 0·1.

Basic rail steel produced with 8 per cent. of spiegel, and containing 0·25 per cent. more carbon than the ingot iron, but otherwise similar in composition, gave a gas containing:—Carbonic oxide, 68 per cent.; hydrogen, 16·2; nitrogen, 11·0; carbonic anhydride, 4·8.

The development of gases in the mould is very violent with basic Bessemer steel while the metal is still quite fluid, but decreases as solidification sets in. Analyses were made of the gas escaping at both these periods, with the following results:—

	Ingot Iron.		Rail Steel.	
	1st Period.	2d Period.	1st Period.	2d Period.
Carbonic oxide . .	77·9	62·6	81·7	54·1
Hydrogen	5·7	12·6	8·2	38·6
Nitrogen	14·7	23·2	9·5	3·5
Carbonic anhydride .	1·7	1·6	0.6	3·8
	100·0	100·0	100·0	100·0

The results of the experiments show that the first portion of gas which causes the frothing of basic steel is almost wholly carbonic oxide, but that during the settling other gases are given off, more nearly approaching in their composition those arising from acid steel. Other analyses showed that basic metal before deoxidation is in the same position with regard to absorbed gases as Bessemer or Siemens-Martin metal.

In experiments which were made with the object of determining the reactions occurring during the deoxidation and re-carbonisation of the oxidised metal, it was found impossible to determine the quantities of the substances consumed for this purpose in the presence of slag which produced secondary reactions. There was, consequently, no other method that could be adopted except to deoxidise the metal in the mould itself; therefore the substances to be added were run in simultaneously with the steel, and the mixing was still further promoted by stirring with an iron hook. The following are the results of some of the experiments :—

Spiegeleisen.—If added to the oxygenated basic Bessemer metal in the mould, it causes a very violent reaction, and a spiegel flame a metre high, the steel boiling over the edge of the mould even when the latter is only half full. After the lapse of half a minute the steel sinks, scatters, and solidifies with moderate rising into porous ingots.

The ingot weighed 232 kilogrammes, the spiegeleisen added 14·75 kilogrammes.

	Analyses. C.	Si.	Mn
Spiegeleisen . . .	4·225	0·411	8·118
Steel below . . .	0·228	0·020	0·658
Steel above . . .	0·257	0·014	0·661
Steel average . .	0·242	0·017	0·659
Steel before addition .	0·020	0·016	0·160
Added . . .	0·268	0·026	0·516
Theoretical result .	0·297	0·042	0·676
Actual result . .	0·242	0·017	0·659
Consumed . . .	0·055	0·025	0·007

From this the quantities of oxygen present may be calculated—

0·071 0·028 0·003

The quantity of carbonic oxide formed, amounts consequently to nearly eight times the volume of the steel at 0°. The gas collected seven minutes after pouring contained—Carbonic oxide, 58·3 per cent.; hydrogen, 30·9; nitrogen, 6·8; carbonic anhydride, 4·0 = 100 per cent.

Spiegeleisen.—If added to basic ingot iron produced with 2 per cent. of ferromanganese in the converter and showing no red-shortness, rather active boiling takes place and a spiegel flame rises. In other respects the charge behaved as in the previous experiment. The steel ingot (C. 0·039 per cent.; Si 0·014; Mn 0·353) weighed 272 kg. and the Spiegeleisen (C. 4·262 per cent.; Mn 7·944; Si 0·351) which was added, 11·83 kg.

There were consumed—C. 0·019 per cent.; Si 0·011. The equivalent quantities of oxygen are—0·025 per cent.; 0·012.

The steel must therefore have developed a volume of carbonic oxide 2·6 times as great as its own volume at 0°. Two samples of gas were taken: the one (*a*) after seven minutes, the other (*b*) after twelve minutes.

(*a.*) Carbonic oxide, 56·4 per cent.; hydrogen, 29·6; nitrogen, 10·6; carbonic anhydride, 3·4 = 100 per cent.

(*b.*) Carbonic oxide, 42·1 per cent.; hydrogen, 42·8; nitrogen, 11·1; carbonic anhydride, 4·0 = 100 per cent.

Spiegeleisen.—If added to basic rail steel containing 0·25 per cent. of gas there is no boil. An ingot formed by the addition of 15 kg. spiegel to 250 kg. steel showed scattered blowholes, and a gas was evolved which contained:—Carbonic oxide, 55·2 per cent.; hydrogen, 37·9; nitrogen, 3·2; carbonic anhydride, 3·7 = 100 per cent.

Ferrosilicon.—If to basic metal formed without any addition, ferrosilicon is added in a sufficient quantity to form a steel containing 0·3 per cent. silicon, every visible development of gas ceases at once. The steel is perfectly quiet and does not scatter. It rises a little in solidifying, and contains a moderate number of chiefly sporadic blowholes. It was found impossible to obtain even an approximately close ingot in any of the four experiments. The steel still showed slight red-shortness, which was undoubtedly not due to sulphur, the quantity of which amounts at Bochum to only 0·07 per cent.

In the first experiment the ingot weighed 286 kg.; the ferrosilicon added, 9·74 kg. The steel contained originally—Carbon, 0·033 per cent.; silicon, 0·033; manganese, 0·160. The ferrosilicon contained—Carbon, 1·641 per cent.; silicon, 9·864: manganese, 2·049. There were consumed—Carbon, 0·030 per cent.; silicon, 0·120; manganese, 0·031.

The equivalent quantities of oxygen are—Carbon, 0·040 per cent.; silicon, 0·137; manganese, 0·012.

The ingot still gave off so much gas that after seven minutes a tube was filled with it, the sample consisting of—Carbonic oxide, 32·6 per cent.; hydrogen, 54·0; nitrogen, 7·5; carbonic anhydride, 5.9 = 100 per cent. Similar results were obtained in the other experiments.

Silicomanganese.—Its addition to oxygenated basic metal has an absolutely quieting effect upon the steel. The ingot is free from pores. There is hardly any liberation of gas; even exhalation from the solidified ingot being suppressed, so that it was not possible to fill a small tube. The resulting steel is of good quality. In one of the experiments the weight of the ingot was 285 kilogrammes; and that of the addition was 14·85 kg.

The steel contained originally—Carbon, 0·033 per cent.; silicon, 0·021; manganese, 0·212. The silicomanganese contained:—carbon, 3·127 per cent.; silicon, 6·105; manganese, 28·550. There were consumed:—Carbon, 0·020 per cent.; manganese, 0·064. The equivalent quantities of oxygen are:—for carbon, 0·027 per cent.; for manganese, 0·026.

The author is of opinion that the only safe conclusion to be drawn from these laborious analyses is that the quantity of the substances removed by deoxidation is so small that it might almost be classed among experimental errors.

In remarking upon the effect of silicomanganese, he states that a steel is obtained which neither scatters nor rises, nor yet exhales gases, which fact is unique in the metallurgy of iron, as every other description of iron exhales gases after solidification, and a small tube may be filled from the gases rising from a close ingot of Bessemer, Siemens-Martin, or crucible steel, forty-five minutes after pouring. The author contrasts his experiments with those of M. Pourcel,* and concludes that the divergence in the nature of the results must be due to the latter having probably made the additions in the ladle or even in the furnace. He is of opinion that the cause of scattering is due to supersaturation of the metal with gas, and abandons his former theory that it was due to a difference in the solubility at different temperatures. He also believes that hydrogen and nitrogen alloy with the iron, while the carbonic oxide is only held in solution.

* This Journal, 1882, p. 509.

VI.—*STATISTICS.*

Imports and Exports.—The imports and exports of coal, iron, and steel during the year 1883 were as follows * :—

	Imports.	Exports.
	Metric tons.	Metric tons.
Coal	2,181,182	8,703,970
Coke	166,310	602,139
Pig iron	274,830	259,014
Scrap iron and blooms	9,171	92,503
Wrought iron	16,352	171,280
Rails	1,485	176,178
Plates	2,990	52,299
Wire	3,849	203,627
Manufactured iron	17,595	178,062
Needles	803	7,167
Lignite	3,319,944	45,789
Iron ores	800,372	1,886,450

Coal.—The total quantity of coal exported from Germany in 1883 amounted to 8,703,970 metric tons. The details were as follows:—

Exported to	tons.
1. Holland	2,753,290
2. Belgium	771,140
3. Hamburg and Bremen	603,830
4. Norway and Sweden	9,310
5. France	1,218,040
6. Switzerland	553,120
7. Italy	49,390
8. Austria	2,315,510
9. Russia	405,570

The total quantity exported has constantly increased during the last seven years, as may be seen from the following figures :—

	Tons.
1877	5,007,368
1878	5,838,910
1879	5,999,182
1880	7,236,465
1881	7,458,245
1882	7,631,635
1883	8,703,970

The production of coal in the Dortmund mining district amounted, in 1883, to 27,862,956 tons from 195 collieries, 97,564 workmen being employed. The production of the Saarbrücken collieries in 1883 was 5,892,822 tons. The collieries of Upper Silesia produced 11,720,641 tons in 1883. 91 collieries were working, and 36,916 workmen were employed.

* *Berg- und Hüttenm. Zeitung*, 1884, p. 121.

The ironworks of the Dortmund district produced, in 1883, 1,064,564 tons of pig iron, 569,644 tons of wrought iron, and 930,690 tons of steel.

The production of Upper Silesia in 1883 was 383,476 tons of pig iron, 261,729 tons of bar iron, and 32,046 tons of steel.

Mineral Statistics of the German Empire.—The following are the results of the official preliminary returns * of the production of the mines and works of the German Empire, including Luxemburg, during the year 1883:—

	Metric tons.	Value.
		£
Iron ores	8,736,426	1,949,707
Coal	55,888,490	14,678,040
Lignite	14,334,966	1,935,767
Pig iron made from charcoal . . .	42,622	243,294
Pig iron made from coke and mixed fuel	3,377,013	8,803,075
Total of pig iron . .	3,419,635	9,046,369
Foundry iron	616,126	5,639,017
Bars	115,608	525,992
Cement steel	427	5,155
Finished products	1,295,200	9,887,518
Total of weld-iron . .	1,411,235	10,418,665
Steel ingots and finished products . .	1,009,505	8,099,476

The final figures for the production of the mines and metallurgical works of the German Empire, including Luxemburg, for the year 1882, have been recently issued by the Imperial Statistical Office,† and the details are as under:—

Iron Ore.—The production of iron ore was 8,263,254 tons, valued at £1,959,083, from 849 mines, employing 38,783 workmen.

Pig Iron.—The total production of pig iron was 3,379,806 tons from 137 works. Of this total 42,230 tons were made from charcoal, 3,335,358 tons from coke, and 3218 from mixed fuel. The quantity of native ores treated was 7,482,897 tons, together with 717,743 tons of foreign ores. The number of workmen employed was 23,015. 261 blast furnaces were in blast out of a total of 316. There were produced

* *Berg- und Hültenm. Zeitung*, 1884, p. 254.

† *Stahl und Eisen*, vol. iv. p. 121.

272,151 tons of foundry pig, 1,153,083 tons of Bessemer pig, 1,901,541 tons of puddle pig, and 37,195 tons of castings.

725,127 tons of pig and scrap iron were worked, producing 625,477 tons of castings. This was the production of 1061 works, in which 40,605 workmen were employed. 1547 cupola furnaces, 109 reverberatory furnaces, and 343 other furnaces were in operation.

Weld Iron.—335 works manufactured weld iron, 57,190 workmen being employed. The production was 1,586,153 tons of finished products. The furnaces in operation were, 1849 puddling furnaces, 153 fineries, 1002 reheating furnaces, 526 heating furnaces, 6 cementation furnaces, 8 bloomeries, and 228 other furnaces.

Ingot Iron.—75 works manufactured ingot iron, 27,974 workmen being employed. The quantity of iron treated was 1,430,828 tons, and 1,074,806 tons of manufactured ingot iron were produced. There were in operation 60 Bessemer converters, 41 open hearths, 4 crucible furnaces, 163 cast-steel furnaces, 95 cupola furnaces, 389 heating furnaces, and 45 other furnaces.

Coal.—52,118,595 tons of coal, valued at £13,392,868, were produced; 195,958 workmen being employed. 13,259,616 tons of lignite, valued at £1,807,778, were also produced, 25,546 workmen being employed.

INDIA.

The South Rewah Coal-fields.—According to the annual report of the Geological Survey of India,* regular mining exploration of the Umaria coal-field has been commenced by opening a shaft of 10 feet in diameter, and it is fully expected that, at the close of the current season, a sufficient judgment may be formed of the value of the coal-seam. It is also hoped that the survey of the much larger Sohagpur coal-field will be completed during this field season. In connection with the coal-fields of South Rewah, the resources of iron, for which the north of Jubulpur district has long been noted, assume much importance. Mr. Mallet's report on the nature and extent of the ores, shows how exceptionally favourable all the other conditions are for extensive iron manufacture if the coal be found suitable.

The Choi Coal Exploration.—This exploration was suggested and carried out by the Department of Public Works.† The locality is in the Chita range, ten miles south of Attock. The several borings put down show that the prospects of finding any sufficient quantity of workable coal either at Choi, Mungi, or the country lying to the west and east, is very slight. The coal itself is of poor quality; it is, however, said to be a good gas-producer. Everything has been done with a view of finding a profitable seam of coal; the borings and trial-pits have been put down in the most advantageous places, but without the success so confidently expected.

Mineral Resources.—According to a blue-book recently published, iron has been found in almost every district of India, and has been worked on a small scale with charcoal by the natives. English agency has attempted iron manufacture in several districts, but in no case altogether successfully. There are only three probable centres of iron manufacture on a large scale: the Bengal Ironworks, the Jubulpur district, and the Chanda coal and iron fields. The probable annual output of the last-mentioned iron-fields has been estimated at 260,000 tons of iron and steel. The native mining industry in Madras, producing iron in small quantities, aggregated for the year 1882 an output of the value of £4658.

* *Records of the Geological Survey of India*, vol. xvii. p. 9.
† Ibid., vol. xvii. p 73.

The opinion is expressed that Indian coal has a great field before it in satisfying the demand of the railways, on account of the growing scarcity of wood. At present, however, Indian coal cannot compete in price with English coal on the Bombay and Madras railways. The quantity of English coal consumed on Indian railways in 1882 was 175,951 tons, and English patent fuel 9360 tons; while of Indian coal 383,709 tons were consumed. The output from the sixty-six mines in Bengal during 1881 was 930,203 tons. The outputs from the Mohpani and Warora mines, in the Central Provinces, were 8019 and 59,508 tons respectively. In Assam there is said to exist a procurable quantity of coal amounting to 40,000,000 tons.

Imports of Iron into India.—Mr. J. E. O'Connor, Assistant-Secretary to the Government of India in the Department of Finance and Commerce, has published a review of the trade of British India, with foreign countries, for the official year ending March 31st, 1883, and he devotes a portion of this report to the imports of iron. He mentions that the quantity of iron imported into India has increased by a third in the last five years, and he gives the following statistics as representing this importation:—1878–79 = 2,365,306 cwt.; 1879–80 = 2,111,156 cwt.; 1880–81 = 2,665,604 cwt.; 1881–82 = 2,452,507 cwt.; 1882–83 = 3,151,935 cwt. The author states that the trade in iron advanced very briskly during the past year, the prices of iron having fallen low in England. With the exception of about 192,000 cwt. of cast iron and old iron for remanufacture, the whole of the iron imported into India for the year 1882–83 was manufactured iron, bar, angle, bolt, rod, hoop, galvanised, sheet and plate, wire, beams, girders, pipes, nails, screws, &c. It is mostly in these forms, and in the form of rails, that India, not as yet an iron-manufacturing country, takes the iron she wants. The Government is now carrying on the works of the Bengal Iron Works Co., situated in the Raniganj district, with the hope of inducing capitalists to take up the concern and prosecute work there vigorously. There seems to be a fair prospect of a wealthy company taking up the works and carrying them on to the fullest extent for the production of cast and wrought iron, and, eventually, of steel. Of the old iron imported into India for remanufacture, the greater part was imported into Madras from Ceylon. Of all other kinds England as yet has practically the monopoly, the imports being 3,071,164 cwt. Belgium is the only other country which sends any appreciable quantity to India; the imports of Belgian iron in 1882–83 amounted to 65,066 cwt.

ITALY.

Statistics.*—As the latest statistics given in this *Journal* (1883, p. 453) are those for the year 1879, the figures for 1880 may not be without interest.

The production of iron ore in 1880 was 290,974 metric tons, valued at £125,114; the Elba mines alone supplying 275,245 tons. 60,000 tons of metal were produced. Only one ton of ore was imported. The exportation of iron ores during 1880 amounted to 399,721 tons.

The quantity of mineral fuel produced was 138,999 tons. This was composed of anthracite, lignite, and bituminous schist, but does not include peat. The yield of the latter was 100,000 tons; 9069 tons of mineral fuel were exported to Switzerland and Austria, and 1,737,746 tons of coal and coke were imported.

* *Notizie statistiche sulla Industria mineraria in Italia dal* 1860 *al* 1880, p. 406.

JAPAN.

Experiments to Detect the Presence of Gas in Collieries.—Professor Milne of Japan has recently made a new move in the direction of investigating seismic phenomena. He has made preparations for the establishment at Takashima, near Nagasaki, of an underground observatory. The workings in the colliery at that place extend beneath the sea, and have a total length of seventy miles. About 2500 people are employed in them, and the output of coal is about 1200 tons a day. The great heat due to chemical decomposition and the escape of fire-damp makes the mine very dangerous. The experiments are: The observation of earth currents; listening in a telephone to the sound produced by the movement of a microphone placed in the solid rock; the observation of earth tremors; the observation of two delicate levels to see if the seasonal movements of the soil on the surface exist also underground; attempts to measure the influence of the tide in producing a bend in the roof of the mine. One practical object of the observations is to ascertain whether any of these phenomena are connected with each other, and especially with the escape of fire-damp in the mine. At present it appears that the gas shows itself eight hours before a fall in the barometer, and therefore the indications of the latter are useless as danger-warnings.*

New Ironworks in Japan.—It is stated † that new ironworks will shortly be opened by a Japanese capitalist at Kobe, and that several hundred workmen trained at the Akabane Ironworks, and elsewhere in Tokio, have been engaged by the projectors. Iron ore of a very fine quality having been obtained from the Shimonida Mine, it will be employed hereafter for the manufacture of the armour for war-vessels built by the Japanese Naval Department.

Imports of Iron and Steel in 1882.—M. Scribe, the Belgian Consul-General for Japan, states in his last report that the imports into

* *Japan Gazette*, Jan. 12, 1884. † *Iron*, vol. xxiii. p. 481.

Japan in 1882 of iron and steel, raw and manufactured, were of the value of 1,519,500 dollars, the principal classes being as under :—

	Weight. Cy.		Value. Dollars.
Bar, hoop, sheet, and nail plate	25,048,100	...	674,800
Iron rails	12,418,217	...	217,600
Pig iron	8,955,600	...	95,400
Iron articles	——	...	79,100
Old iron	5,285,000	...	71,300
Iron wire	1,249,300	...	60,500
Anchors and chairs	——	...	33,400
Steel, raw	1.118,000	...	67,500
Steel, manufactured	——	...	32,800
Steel wire	1,580,500	...	47,100

M. Scribe, in comparing these figures with those for previous years, states that pig iron has only been a regular article of import since 1880. Articles made of iron have considerably diminished in value since 1875, when they reached their maximum of over 250,000 dollars. More iron wire was imported in 1882 than in any previous year; there were imported in 1881, 790,900 cy., value 38,100 dollars. The import of steel (raw) attained its maximum in 1878, when it reached the value of 130,900 dollars; it fell to 966,000 cy., value 52,900 dollars, in 1881, so that the import for 1882 shows considerable improvement. In 1881 the import of steel wire was of the value of only 3064 dollars; and the quantity of manufactured steel imported in 1881 was of the value of but 3000 dollars. The Consul says he is informed that the great increase of the imports of these last two articles in 1882 over the quantities imported in 1881, is chiefly due to the large quantities of wire-nails imported from England, which had been badly classified by the Japanese authorities. From the last report of the Consul of the German Empire at Yokohama it appears that the quantity so imported was about 20,000 piculs of 135 lbs. each. The price obtained for bar iron varied from 2·50 dollars per picul in January to 2·92 dollars in October. English large-sized nail rod sold in May for 2·30 to 2·80 dollars per picul; Belgian rod selling for 10 cents less. English small-sized nail rod sold in July for 2·90 to 3·17 dollars per picul. At the end of the year the quotation for English rod of this size was 2·90 to 3·12 dollars per picul, and similar Belgian rod 2·80 to 3·02 dollars. No. 3 Cleveland pig varied in price during the year from 1·25 to 1·30 dollars per picul in January to 1·50–1·55 dollars in July. Plate and sheet, 12 to 20 W. G., sold during the year at prices varying from 3·10 to 3·25 dollars per picul. Bar steel sold at prices of from 4·00 to 4·50 dollars per picul.

MEXICO.

The Durango Iron Mountain.—For many centuries the great iron mountain near Durango has been one of the wonders of Mexico.* Just beyond Durango the Cerro de Mercado rises from the great plateau, as a hill one mile long, a third of a mile wide, and 600 feet high. It is probably formed of one or more immense veins of specular iron ore, standing nearly vertical, the fragments of which have been thrown down so as to form a talus.

A large number of samples were recently taken from various parts of the mountain to indicate the peculiarities of the formation, and twenty-seven typical specimens were forwarded to Mr. A. S. M'Creath, Chemist of the Second Geological Survey of Pennsylvania, with a request to make an analysis to represent the average. The result of his analysis was as follows :—

	Per cent.
Magnetic oxide of iron	2·071
Ferric oxide	77·571
Manganic oxide	0·113
Titanic anhydride	0·710
Lime	5·050
Magnesia	0·364
Sulphuric anhydride	0·212
Phosphoric anhydride	3·041
Loss on ignition—water, &c.,	1·984
Silica	7·760
Alumina, &c., undetermined	1·124
	100·000
Metallic iron	55·800
Manganese	0·070
Sulphur	0·085
Phosphorus	1·328
Phosphorus in 100 parts iron	2·379

Some of the samples, confined to a limited area on the northern face of

* *Engineering and Mining Journal*, xxxvii. p. 199.

the mountain, showed crystals of phosphate of lime. Mr. M'Creath made an analysis of 17 samples, with the following results :—

	Per cent.
Metallic iron	62·775
Phosphorus	0·288
Siliceous matter, including a little titanic acid	5·240
Phosphorus in 100 parts of iron	0·458

The samples of pig and bar-iron yield respectively the following results :—

	Pig iron.	Bar iron.
Silicon	0·771	0·105
Phosphorus	0·428	0·193

RUSSIA

The Iron Industry of Russia.—The production of iron in Russia is, according to G. de Cuyper,* still very restricted, a large portion of the metal required being imported. For quality and abundance of ores, no other country is so favoured.

The eastern side of the Ural chain is remarkable for its rich magnetic ores, yielding 66 to 67 per cent. of iron; while the western side presents immense masses of limonite, hæmatite, and spathic iron ore. In Central and Eastern Russia, lake iron ores abound, and Western Russia comprehends vast fields of limonite and of sphærosiderite disseminated in reniform masses through beds 2 to 4 feet thick. The Carpathian range is equally rich in iron ore in the form of limonite. Eastern Poland contains brown hæmatite, giving 30 to 40 per cent. of iron, and alluvial ores with 25 to 30 per cent. In the western portion of the kingdom sphærosiderite occurs in the Coal-measures, and brown hæmatite in Devonian limestone. The first ore gives 30 to 40 per cent. of iron, and the second an average of 30 per cent. Finland is rich in lake ores, and the mountains of Nyland and Abo contain magnetic ore in lodes. Except in the works of the Danube, Donetz, and of Western Poland, iron is manufactured with charcoal as fuel, and consequently the forests are becoming rapidly exhausted. The resources of the Danube coal-basin might be brought to bear upon those districts where mineral fuel is absent, if they were developed by proper working.

According to the latest official statistics the working of the 956 iron mines in Russia in 1880 furnished 1,007,959 metric tons of ore. The production of pig iron was 436,000 tons, and the imports 240,000 tons; the consumption being 676,000 tons. There were 189 works, 41 of which were idle. In the 148 remaining, 19 of which belonged to the Government, 207 blast furnaces were in blast, producing on an average 2100 tons of pig iron; while in England the average yield per blast furnace is 14,600 tons. The production of iron and steel in 1880 was

* *Revue Universelle des Mines*, vol. xv. pp. 56–79.

592,070 tons. The imports amounted to 216,631 tons, and the consumption to 808,701 tons. There were 252 iron mills, 60 of which were idle. The 192 mills in operation, 16 of which belonged to the Government, employed 464 puddling furnaces and 602 reheating furnaces.

The comparison of Russia with other countries, according to the production of pig iron in 1880, gives the following results :—

	Tons.
England	7,808,000
United States	3,886,000
Germany	2,720,000
France	1,696,000
Belgium	592,000
Austria	440,000
Russia	436,000
Sweden	400,000

Coal and Iron.—The coal and iron industries and the railway system in the valley of the Donetz are showing very fair progress.* The official estimate for the year 1883 of the output of coal in the Donetz Valley, a territory about 180,000 square miles in extent, was 166,000,000 poods. Through this district a railway system winds, having stations near the principal collieries, of which there are about 100 working. At Grushefka, about fifty miles to the north of Rostoff, are the Azof Coal Company's mines of anthracite coal. About 250 labourers are at present employed in them night and day, the manager and foremen being Englishmen. Open oil-lamps are used; and the men are paid according to the amount of work done. The prices of anthracite coal at the pit at the end of 1883 were :—For large coal, 1st quality, 10½ copecs per pood ; 2d quality, 10 copecs per pood ; small coal, 9½ copecs per pood ; and for a waggon-load of 509 poods delivered at Taganrog, 75, 72, and 70 roubles respectively. At Hughessofka there are works belonging to the New Russia Company which turn out 500 rails per day of twenty-four hours. The price of pig iron at the works costs 70 copecs per pood, and delivered at Rostoff and other places, 80 copecs per pood. English pig, which is superior to that of the New Russia Company, costs 1 r. 10 copecs per pood at Rostoff. There are three blast furnaces at the company's works, each producing 140 tons per day, the oldest having been lately repaired after eleven years' continual usage. The pits belonging to the company turn out 1,000,000 poods of bituminous coals per month. Brickmaking from fire-clay is carried on, on a scale sufficiently large to meet all the requirements of the works, and the hearths of the furnaces are made from a fire-resisting stone found in the neighbourhood. A branch line connects the works with the nearest station on the Constantinofka-Maripol line. The

* *Mining Journal*, vol. liv. p. 724.

coal-pits are close to the works, but the iron-mines are distant about twenty miles. Manganese ore for smelting is imported at much cost from the Caucasus.

Manganese Ore in the Caucasus.—An extensive discovery of pyrolusite has been made in the valley of the Koirila, a tributary of the Rion or Phasis, by the geologists Batsevitch and Simonovitsch.* The deposit occurs in the Miocene sandstone, and has been proved over several square miles; it consists of seven seams of good ore, from 1 to 6 yards in thickness, with interposed clay, the total thickness varying from 2 to 3 yards. The mineral is partly compact, partly oolitic, partly porous, and has to be cleaned by washing, which operation, from local causes, offers some difficulties. The porous portion is too rich in phosphorus (of which it contains 1 per cent.) to be fit for metallurgical use. A specimen of the compact ore contained 54·9 per cent. manganese, 1·5 iron, 4 silica., 4·5 alumina. Although the ore is got cheaply, its further transport is at present expensive, and the cost at which it has been brought to Marseilles, 100 francs per ton, appears too high for an ore with but 53 to 54 per cent. manganese.

The Influence of Punching Holes in Soft Steel.—V. N. Beck-Guerhard has lately conducted a series of experiments at the Poutiloff Works (St. Petersburg) respecting the influence of punching holes in soft steel, the results of which he has communicated to a recent number of the Russian Mining Journal.†

The experiments commenced by testing rail fish-plates in order to ascertain if the resistance of the fish-plates is decreased by punching instead of drilling the bolt holes. For this purpose forty-two fish-plates were cut from the same bars of mild steel, containing from 0·1 to 0·15 per cent. carbon, and bolt holes, of the same dimensions, were drilled in the first fourteen, cold punched in the second fourteen, and in the last fourteen they were punched after heating the plates to a dark-red heat. To these fish-plates short pieces of rails were fastened. The twenty-one joints so made were tested under a pressure of 9·7 tons; the distance between the supports being 3 feet 6 inches. The whole pressure was supported only by the fish-plates. The deflections are shown in the following table:—

* *Zeitschrift des Vereins Deutscher Ingenieure*, vol. xxviii. No. 6.
† Translated for this Journal by Mr. John Hughes.

Joints with Drilled Holes.		Joints with cold Punched Holes.		Joints with hot Punched Holes.	
Temporary Deflection.	Permanent Deflection.	Temporary Deflection.	Permanent Deflection.	Temporary Deflection.	Permanent Deflection.
39·15	33·95	49·00	43·55	61·90	56·50
50·00	44·00	47·85	42·35	46·20	42·00
43·90	38·15	52·60	47·00	57·25	52·00
47·15	41·10	42·30	37·00	49·50	44·00
56·20	50·00	49·85	44·00	47·20	42·75
53·20	48·25	40·35	35 50	61·00	55·50
46·10	40·80	43·35	38·10	57·00	52·30
Aver. 47·95	42·32	46·47	41·07	54·29	49·29

Twenty other fish-plates were made from a steel containing 0·05 per cent. more carbon, and the holes punched hot; the ten joints made with them were tested under the same conditions as the former, and showed the following deflections:—

Temporary Deflection.	Permanent Deflection.
28·00	25·10
26·50	21·30
24·35	20·25
29·00	24·30
26·10	21·25
25·00	20·35
27·00	22·50
25·85	23·20
25·50	21·15
27·25	22·80

All the joints tested under a pressure of 9·7 tons were afterwards tested under a pressure of 14·5 tons, and not one fish-plate showed cracks or signs of deterioration. These tests proved that punching holes cold in such a soft steel (from 0·10 to 0·15 per cent. carbon) does not practically affect the fish-plates, and that a very little increase of hardness has much more influence on the resistance of the joints than the manner in which the holes were made.

For the next experiments trial bars, 10 inches long and 1 inch wide, were made from mild steel $\frac{1}{2}$ and $\frac{5}{8}$ inch thick. From each plate 6 bars were prepared. The first was left untouched; in the second a hole $\frac{1}{2}$ inch in diameter was drilled; in the third a hole $\frac{1}{2}$ inch in diameter was punched cold; the fourth was treated the same way as the third, but annealed; the fifth was punched with a $\frac{1}{2}$-inch hole hot, and in the last a $\frac{3}{8}$-inch hole was punched cold, but afterwards drilled to $\frac{1}{2}$ inch in diameter. These bars were tested for tensile strength, and the results are shown in the following table. Elongation is measured on 8 inches and given in percentages, and the breaking strain is in tons per square inch:—

	1. Mild Steel with 0·12 C.		2. Mild Steel with 0·12 C.		3. Mild Steel with 0·12 C.		4. Mild Steel with 0·12 C.		5. Mild Steel with 0·12 C.		6. Mild Steel with 0·12 C.		7. Spring Steel with 0·3–0·5 C.		8. Spring Steel with 0·3–0·5.	
	Breaking strain.	Elongation.	Breaking strain.	Elongation.	Breaking strain.	Elongation.	Breaking strain.	Elongation.	Breaking strain.	Elongation.	Breaking strain.	Elongation.	Breaking strain.	Elongation.	Breaking strain.	Elongation.
Bar untouched . . .	26·82	25·00	31·59	19·58	25·67	26·72	32·22	24·01	29·70	25·00	29·10	26·00	55·00	12·70	53·80	14·42
Bar drilled . . .	25·75	25·07	30·96	14·57	25·27	25·80	30·39	24·57	28·80	25·30	28·60	25·80	43·90	10·88	44·40	10·64
Bar cold punched . . .	23·04	23·10	27·05	10·88	24·07	23·83	26·53	23·59	26·10	23·30	26·90	22·80	30·30	10·39	34·40	10·39
Bar cold punched annealed .	28·88	25·07	31·98	14·57	27·09	25·31	30·26	23·83	29·20	25·30	28·90	25·80	47·60	10·64	48·67	11·13
Bar hot punched . . .	27·08	25·07	30·71	13·59	26·47	26·30	30·26	23·35	29·80	25·80	29·40	25·30	46·00	10·88	49·61	11·13
Bar punched and drilled .	27·40	25·31	31·15	14·57	26·61	25·80	32·15	24·33	30·30	24·00	29·90	25·30	47·20	10·64	47·06	10·64

These tests show that punching cold, compared with drilling, decreases both resistance and elongation, that annealing cold punched bars and hot punching are nearly equivalent, and that the after drilling of a cold punched hole reduces the influence of punching.

In order to ascertain the influence of punching when the hole is punched not in the bar itself, but close to it, two trial-bars were cut from a fish-plate, in which two holes were punched in one half, the other half remaining untouched. The punched half of the bar gave 32·29 tons with 22·5 elongation, the untouched half of the bar gave 30·55 tons with 26·7 elongation; in other words, the hardness of the metal was increased in the neighbourhood of the punching.

As a third experiment, holes were punched at the end of a bar of mild steel. The ends were then bent, one downwards in the direction of the punching, the other in the opposite direction. The end, bent downwards, could be bent to a right angle without showing any cracks, while the other end always showed large cracks. The same test made with the same bar, but with drilled holes, gave other results. Both ends can be bent upwards or downwards without cracks, and the difference between the top and bottom of the holes cannot be seen. This fact induced the study whether microscopic cracks are not formed on the bottom of the punched holes. For this purpose small plates were prepared 5 inches × 3 inches × $\frac{1}{2}$ inch of steel of different hardness, with shaped sides and polished surfaces. In these plates, three holes of $\frac{3}{4}$-inch diameter were made, one punched, the second drilled, and the third punched $\frac{5}{8}$ inch, and then drilled to $\frac{1}{2}$ inch. After this the edges of the holes were examined under the microscope, and in no case were cracks or flaws found. In the drilled holes the edges were clean enough. In the punched holes only the top side was clean, showing a round edge; whilst the bottom side presented a sharp edge, in some places broken away, and drawn out with deep cavities discovering the crystalline structure of the metal. In short, under the microscope a clear picture of the rough destruction, caused by the punching, is seen. The inside of the holes was smooth for one-third of the height, with visible traces of the friction of the punch, the remaining two-thirds is of larger diameter with two or three large cracks broken off.

Instead of the microscopic crevices looked for, the author discovered another interesting phenomenon. On the smooth polished surface of the plates appeared, clearly visible to the naked eye, a design composed of curved lines, crossing each other and disposed like bundles or sheets, more or less tangential to the circumference of the hole. These lines do not appear round the drilled holes, but round the after-drilled holes they appear with the same clearness as round the holes punched to the full diameter. The author has not observed these lines in puddled iron plate.

He observed them in the softest ingot metal; in steel containing 0·5 per cent. carbon they were less visible, and, finally, with 0·6 per cent. carbon they could not be remarked. With the increased thickness of the plates the number and clearness of the lines increased. The shape of the holes has also some influence on the disposition and dimensions of the lines. On all the small plates, 5 inches × 3 inches, the lines appeared as very small indentations, while on the larger specimen, 10 inches × 10 inches, the lines were convex, gradually lowering to the end of the divergent lines, and imperceptibly flowing together with the surface of the plate. In the small specimens the lines reaching the edge were terminated with a plane surface; whereas in the fish-plates the lines most developed were visible beyond the edge of the specimen, and after crossing the lines projected in some cases on the opposite side of the plate. After heating and cooling the lines did not disappear; they were, however, less distinct. In order to determine how far from the hole the lines develop, a mild steel plate, 10 inches × 10 inches × $\frac{5}{8}$ inch, was prepared with polished surfaces, and in the middle of it an inch hole was punched. Around the hole a very clear design was obtained, the lines being convex, so that they could be felt with the finger. The surface of the plate was then corroded with acid, which caused all the convex lines to disappear.

In order to see if the punching of the hole or the lines have an influence on the resistance of the metal, and how far this resistance acts, the plate was cut into eight bars, four from each side of the hole. The bars tested gave the following results :—

No.	Breaking Strain. Tons.	Elongation. Per Cent.
1	26·98	22·7
2	25·46	19·0
3	27·20	19·0
4	27·43	23·0
5	27·66	20·4
6	27·67	26·8
7	25·64	19·54
8	28·22	19.09

No. 1 was from the extreme left, No. 4 close to the hole, and No. 8 from the extreme right. On examining the broken bars, it was remarked that the fracture corresponded with the blow-holes, that the difference in the resistance and elongation is influenced by the same cause, and that such defects in the ingot are much more serious than the influence of the punching. It was further remarked that the surface of the broken bar appeared covered with convex lines which could be felt with the finger. Putting the broken bars together in the same order they occupied in the plates, it appeared the separate lines gave the same design as on the plate before corrosion with acid, accompanied by other lines not seen before.

A similar plate was next prepared from the same sheet, and cut into 8 bars, but without punching before the hole. After fracture the 8 bars still showed the same smooth surface without the slightest line. This test clearly shows that the lines on the plates, annulled by pressing out, and reappearing after the tension of the bars, depend upon the strain in the metal caused by punching holes. This reappearance of the prominent lines after rupture of the bars shows that the metal evidently expanded more between the lines than in those parts of the bars which were covered with lines before the punching-out.

In conclusion, the author states that he considers his experiments far too insufficient for an exact scientific explanation of the causes and laws of the results he has observed.

Russian Steel Rail Works.—A large amount of technical and economical information has been collected by V. N. Beck-Guerhard, Head Government Inspector of the Russian Rail Works. The works described in his pamphlet* are: 1. North Saldinsky Demidoff; 2. Kataffsky Prince Bieloselsky; 3. New Russia Company; 4. Dombroffsky; 5. Poutiloff; 6. Alexandroffsky; 7. Briansk; 8. Warsaw.

1. The North Saldinsky Demidoff Works are situated in the Verchotourskova district, in the government of Perm. Three iron-ore mines belonging to the works are working, and 23 not working. The coal is obtained from the Lounoffsky Colliery. The yearly consumption of fuel amounts to 23,600 cub. faths. wood, 560,000 poods † of coal, and 45,000 korol charcoal. The ore treated is magnetic iron ore with 65·8 per cent. of iron. The works possess three blast furnaces, the heights of which are 52, 55, and 44 feet, and the capacities 4573, 5335, and 3811 cubic feet respectively. The blast has a temperature of 300° C., and a pressure of 3½ inches. The tops are closed, and the gas is used for the boilers. The average life of a furnace is two years. The charge is, iron ore 24¼ poods, lime 1½ poods, sand 1½ poods, slag 2½ poods, charcoal 1 kor. The yearly production is 700,000 poods; the daily production of one furnace being 900 poods. For 100 poods pig iron, 154 poods iron ore and 6 kor. charcoal are required. There are two Bessemer converters; the charge being 235 poods, consisting of pig iron 95·5 per cent., rail ends 4·4, ferromanganese 0·1. The daily production is 2400 poods, from 11 blows; the yearly production of steel being 720,000 poods, not including the production of 700,000 poods of pig iron. The loss in the converter is 7·8 per cent. For 100 poods Bessemer steel the consumption of fuel is: wood, 0·27 cub. ftms.; coal, 2·60 poods; charcoal, 0·44 poods. The ingots are 25 inches high, 9 inches at top, and 10 inches at bottom,

* Translated from the Russian by Mr. John Hughes.

† Pood = 36 lbs; Korol = 70 cub. fathoms.

weight 15·5 poods. Six furnaces heat the ingots, the daily working of one furnace being 650 poods, 0·3 cub. ftms. wood is consumed, and the waste in the furnace is 4 per cent. The horse-power of the rolling engine is 60. The number of cogging grooves 8. The section of ingot is 95 square inches before, and 42 square inches after cogging. There are 4 furnaces for second heating of ingots, the daily production of each furnace being 1950 poods. There are 2 horizontal engines with 150 h.p. for the rolling mills. There are 5 roughing and 6 finishing grooves. The yearly production of rails is 1,000,000 poods, in addition to 10,000 poods merchant ingots, and 15,000 poods for plates.

2. The Kataffsky Works are situated in the government of Ufa. The ore smelted is a brown hæmatite. There are three blast furnaces, each 44 feet high, with a capacity of 1796 cubic feet. The blast has a temperature of 300° to 350° C., and a pressure of $2\frac{1}{2}$ inches. The tops are closed, the gas being used for the hot blast stoves and calcining ore. The average life of a furnace is 9 months. The charge is, iron ore $24\frac{1}{2}$ poods, flux $2\frac{1}{2}$ poods, charcoal 1 kor. The yearly production is 650,000 poods; the daily production of each furnace being 700 poods. There are two Bessemer converters; the charge being 300 poods, consisting of pig iron 84·0 per cent., rail ends 14·2, spiegeleisen 1·8. The daily production is 2800 poods, and the yearly production 767,060 poods. The yearly production of rails is 850,000 poods.

3. The New Russia Company in the government of Ekaterinoslaff possess 4 blast furnaces, 65 feet 4 inches, 50 feet 6 inches, and 39 feet 10 inches high, with capacities of 8470, 5655, 6304, and 1538 cubic feet, respectively. The blast has a temperature of 330° C., and 4 inch pressure. The tops are open; the boilers and hot blast stoves having separate grates. The yearly production is 2,500,000 poods. There are six Siemens-Martin furnaces; the charge in each being 803 poods, consisting of pig iron 48·60 per cent., puddled bar 30·40, steel scrap 17·00, iron ore 2·40. ferromanganese 1·60. The daily production of each furnace is 1452 poods, the yearly production of steel being 2,500,000 poods. The yearly production of rails is 2,000,000 poods.

4. Dombroffsky Works in the government of Petrokoff possesses one blast furnace, 50 feet high, with a capacity of 6350 cubic feet, the yearly production being 1,131,500 poods. This is further treated in eight Siemens-Martin furnaces; the yearly production of steel being 1,300,000 poods. The yearly production of rails is 1,200,000 poods.

5. The Poutiloff Works in the government of St. Petersburg do not make pig iron. They possess eight Siemens-Martin furnaces, one Pernot furnace, and two Bessemer converters. The yearly production of steel is 5,300,000 poods, the yearly production of rails being 4,500,000 poods.

6. The Alexandroffsky Works, in the government of St. Petersburg, possess seven Siemens-Martin furnaces, and produce yearly 2,000,000 poods of steel, the yearly production of rails being 1,800,000 poods.

7. The Briansk Works, in the government of Orel, possess 6 Siemens-Martin furnaces and 2 Bessemer converters. The yearly production of steel is 4,000,000 poods. The production of rails in 1882 was 1,427,749 poods; but it is possible to double it.

8. The Warsaw Works possess 4 Bessemer converters; the yearly production of steel being 4,000,000 poods. The yearly production of rails is 3,360,000 poods.

Estimation of Carbon in Cast Iron and Steel.—Twenty grammes of copper sulphate and 20 grammes sodium chloride are dissolved in water and evaporated to dryness, and 20 grammes of the residue are mixed to a paste by the aid of water with 1 gramme of the finely divided iron which is to be assayed. The mixture is then heated gently in a beaker, first by itself, and then with the addition of hydrochloric acid. The residue consists of impure carbon, and is filtered off on an asbestos filter and burnt in the ordinary way.

If the residue were weighed as pure carbon, the estimate might be as much as 35 per cent. too high; but numerous analyses have led Zaboudsky * to accept the following numbers as representing, with sufficient accuracy, the percentage of pure carbon in the residue:—

	Per Cent.
Spiegeleisen	68·5
White iron	71·0
Grey iron (pure)	71·0
Grey iron (not very pure, containing some combined carbon)	65·5
Cast steel (C=0·5 per cent.)	66·0
Steel (harder)	67·5

As the carbon compounds burn easily and the graphite with difficulty, the method permits of a simultaneous estimation of the carbon present in the iron both in the combined form and as graphite.

Analyses made by the above method, and using Zaboudsky's co-efficients, are more accurate and may be made with as great a rapidity as when Eggert's method of dissolving the iron in iodine is adopted.

Silicon in Pig Iron.—In order to determine the part played by silicon in pig iron, G. Zaboudsky † has made some investigations on two varieties of glazed pig, samples of which were shown by the Demidow

* *Bulletin Soc. Chim.*, 1884, p. 428.

† *Journal of the Russian Chemical Society*, 1883, p. 604.

Works at the exhibition in Moscow in 1882. They gave on analysis the following results :—

	No. 1.	No. 2.
Combined Carbon	0·00	0·58
Graphite	1·94	2·38
Silicon	9·50	5·92
Sulphur	0·020	0·027
Phosphorus	0·11	0·14
Manganese	1·20	1·09

On decomposing these two samples with his mixture of copper sulphate and sodium chloride, Zaboudsky found that one part of the silicon passed into solution, while another part remained in the insoluble residue. In this respect there was, however, a marked difference in the behaviour of the two pig-irons. In the case of No. 1 only $\frac{1}{15}$th to $\frac{1}{9}$th of the total amount of silicon present passed into solution, while with No. 2 almost all the silicon was dissolved and only about $\frac{1}{8}$th remained in the residue. In these residues the silicon is present as its hydrated oxide, the composition approaching the formulæ $(SiO_2)_3\ H_2O$ and $(SiO_2)_4\ H_2O$. The combustion of the residue from No. I. showed it to contain 60·02 per cent. C. and 5·41 per cent. H.

Imports of Iron and Steel.*—The following statistics represent the imports of iron and steel into Russia during 1883, compared with those for the previous year :—

	1882. Tons.	1883. Tons.
Iron and steel goods	27·300	24·600
Wire	9·500	1·400
Tool and other steel	·600 (about)	·300
Steel rails	...	1·350
Iron bars, plates, and sheets	76·200	61·500
Machinery	17·000	16·000

* *The Ironmonger*, 1884, p. 855.

SPAIN.

Iron Ores.—Spain is rich in all kinds of iron ores. According to the official statistics for the year 1881 * there were 771 mines working. At these mines 13,520 workmen and 6 steam-engines were employed. The production amounted to 3,502,681 metric tons of iron ores, with an aggregate value of £378,083 at the mines. Of these ores, 3,088,703 tons were exported, and were distributed among the various countries as follows :—

	Tons.
France	424,736
England	1,984,986
Belgium	70,030
Germany	374,241
Denmark	100
Sweden	708
United States	233,902

Only 266,044 tons were smelted in Spain. The ores were smelted in the following provinces :—

	Tons.
Biscaya	136,812
Oviedo	87,647
Guipuzcoa	17,989
Alava	5,800
Navarra	4,480
Other Provinces	13,316

If the quantity of ore in stock at the end of 1881 is added to the amounts exported and smelted in the country, the total production of 3,502,681 tons is obtained.

Ironworks.—In 1881 only 37 ironworks were in operation. They employed 70 hydraulic motors and 150 steam engines, with 1377 and 5622 H.P. respectively. There were 84 blast furnaces, 18 small furnaces, 103 reverberatory furnaces, 103 puddling furnaces, and 84 forges.

* *Revista Minera y Metallurgica*, vol. xxxv. No. 991.

6811 workmen were employed; but only 266,044 tons of ore were smelted, and not more than 70,944 tons of pig iron were further treated. The total production of pig iron was 114,394 tons. The production of wrought iron was 53,279 tons, 3602 tons of which were manufactured by the direct process and 49,677 tons from pig iron.

The following table shows how unsatisfactory is the relation between the production and consumption of iron in Spain :—

Year.	Production of Wrought Iron.	Importation.	Consumption.
	Tons.	Tons.	Tons.
1879	44,620	82,657	127,277
1880	49,021	84,851	133,872
1881	53,279	114,133	167,412
1882	54,000	114,749	168,749
Totals .	200,920	396,390	597,310

From this it may be seen that Spain, notwithstanding the great abundance of iron ores and coal, produces scarcely one-third of the iron it requires.

Coal. — The following table gives the production of coal in Spain during the year 1881 :—

Province.	Coal.	Lignite.	Peat.	Value.
	Tons.	Tons.	Tons.	
Oviedo	483,634	50	200	13,763,702
Palencia	324,322	...	...	14,728,920
Cordova	368,779	...	...	14,729,089
Seville	56,220	...	...	3,935,400
Gerona	8,017	...	...	2,716,280
Leon	4,800	...	...	320,680
Ciudad Real	4,800	...	400	156,800
Burgos	590	...	...	59,000
Terida	350	3,880	...	122,180
Teruel	...	9,415	...	352,461
Balearic Isles	...	8,900	...	188,180
Guipuzcoa	...	5,965	...	119,300
Santander	...	5,600	...	156,800
Barcelona	...	4,310	...	189,640
Logroño	...	352	...	20,640
Totals	1,271,410	38,472	600	51,560,127

The Orconera Iron Company.*—The mines belonging to this

* *Revista Minera y Metallurgica*, vol. xxxv. No. 993.

company now in operation are the Orconera, Concha, and Cesar. The ores worked consist of red and brown hæmatites, and are locally known as *campanil, vena, rubio avenado,* and *rubio.* The Cesar mine employs, on an average, 400 workmen, and the average annual output is 300,000 tons. The largest quantity raised in a day was 1892 tons. The ore is a very pure rich *campanil.* The deposit is, on an average, 200 ft. thick. The annual output from the Concha mine is 111,000 tons. The Orconera mine is 200 yards above the level of the railway, with which it is connected by a self-acting inclined plane. The ore consists of *vena* and *rubio avenado.* The deposit is, in one part of the mine, 312 ft. thick. The number of workmen employed amounts to 1000, and the minimum output is 2000 tons.

In the year 1882 the total quantity of ore shipped by the Orconera Company was 937,751 metric tons.

Puddling Furnaces.*—It is stated that the first puddling furnaces which have been erected in Spain are about to be started. They have been built by the Bidassoa Iron Foundry and Steelworks.

Amount of Iron Ore Shipped from Bilbao from January 1 to June 30, 1884.—The total quantity exported from Bilbao during the first half of 1884 amounted to 1,709,114 tons. The details are as under † :—

	Tons.	
To Wales—		
Cardiff	303,993	
Newport	202,641	
Port Talbot	5,567	
Swansea	41,253	
Britonferry	7,623	
Porthcawl	11,561	
Mostyn	777	
		573,415
To North-East of England—		
Newcastle	128,546	
Middlesbrough	139,651	
Stockton	27,945	
Sunderland	19,701	
West Hartlepool	19,315	
		335,158
To Cumberland and Lancashire—		
Workington	2,991	
Gartson	1,319	
		4,310
To other parts of England		1,470

* *Le Fer*, March 11th.

† *Mining Journal*, vol. liv. p. 823.

To Scotland—		
Glasgow	176,461	
Grangemouth	7,524	
Ardrossan	12,252	
Bo'ness	4,481	
Ayr	3,115	
		203,833
Total shipped to Great Britain		1,118,186
To Belgium		72,205
,, France		244,749
,, Holland		270,842
,, America		503
,, Corsica		2,629
Total shipped to other countries		590,982
,, Great Britain		1,118,186
Total shipped from Bilbao January 1st to June 30th 1884		1,709,114
,, ,, ,, 1883		1,746,474
Decrease		37,360

SWEDEN.

Iron Ores.—According to Professor G. Nordenström* of the Stockholm School of Mines, the iron ores of Sweden consist principally of magnetic iron ore and red hæmatite occurring in Archæan rocks, in more or less lenticular beds or in irregular masses in gneiss, granulite, mica schist, and crystalline limestone. Lake and bog iron ores are also of frequent occurrence, but are worked only in the province of Smaland. The average annual production for ten years (1870–79) amounted to 748,427 tons of iron ore and 8872 tons of lake and bog iron ore. 70 per cent. of the iron ores raised during this period consisted of magnetic iron ore and 30 per cent. of hæmatite. The gangue (quartz, hornblende, talc, &c.) necessitates the addition of 10 to 25 per cent. of lime, in order to form bi-silicate slags in the blast furnace. Some ores, as, for example, the celebrated Dannemora ore, may, however, be smelted alone. The ores richest in manganese are those from Svartberg. They contain 15 to 20 per cent. of manganese protoxide. The Swedish ores contain 30 to 70 per cent. of iron, and, as a rule, contain but little phosphorus. Among the purest in this respect may be mentioned the Dannemora and Persberg ores, with 0·002 to 0·003 per cent. of phosphorus. As a rule the percentage of phosphorus varies from 0·005 to 0·05. Most of the ores contain a little pyrites, but in the majority of cases the sulphur may be almost completely removed by careful roasting. Some of the ores contain a large quantity of titanium. Among these ores, the magnetic iron of Taberg may be specially mentioned, as it differs in many respects from the ordinary Swedish ores. It is composed of a mixture of magnetite and olivine with grains of plagioclase. It also differs from the other iron ore deposits in belonging to the class of veins and forming an entire mountain 125 meters high. The percentage of iron is, however, only about 30. It contains 6 per cent. of titanic acid and a little vanadium.

Lake Iron Ores belong principally to the province of Smaland, but

* "L'industrie minière de la Suède," Stockholm, 1884.

they also occur in Vermland and Dalecarlia, and, on a small scale, in most of the Swedish provinces. They are often very rich in phosphorus.

Coal.—The Liassic coal of Schonen is not more than 1·5 metre thick, and of this only 0·3 to 0·6 metre is pure coal, the remainder being coal shale. The average annual (1870–79) output of coal amounted to 73,141 tons, or about 10 per cent. of the consumption of Sweden. Consequently considerable quantities of coal and coke are imported. The importation would be still greater if charcoal were not used for the production of pig iron.

Iron Ore Deposits.—The iron ore deposits near Grängesberg, in the provinces of Orebro and Kopparberg, according to P. von Schwarze,* have only recently been investigated, as the ore at this place contains a large amount of phosphorus, and was consequently of but little value before the introduction of the basic Bessemer process. The iron ores occur embedded in gneiss, dipping to the east at an angle of 20° to 45°. The iron ore deposit has a length of about 4150 metres, and is crossed by a number of veins of pegmatite, which, however, have exercised no dislocating action, although it is evident that the ore had attained its present position before the irruption of the pegmatite. The ores occurring in the deposit are specular iron ore, red hæmatite, and magnetite, and as a rule, the more iron they contain, the higher is their percentage of phosphorus. The phosphorus increases towards the hanging wall, and this is probably due to the fact that the magnetic ore is chiefly to be found at this point.

At several places near Grängesberg it has been found that adjoining the foot-wall was a somewhat siliceous red hæmatite, containing about 60 per cent. iron and 0·10 per cent. phosphorus, and occasionally having a thickness of from 6 to 20 feet. Next to this layer of coarse hæmatite came another of much finer grain, sometimes containing crystals of magnetite, and with 70 per cent. iron, and 0·5 to 0·8 per cent. phosphorus. Finally, adjoining the hanging-wall came the highly phosphoric magnetite. In the neighbourhood of the pegmatite veins the hæmatite is frequently changed into magnetite to a depth of several feet. The percentage of sulphur in the ore is very small throughout the whole district. At several points shafts have been sunk to a depth of 500 feet, and the output in the last few years has been at the rate of about 45,000 tons per annum.

The following are analyses of the ores occurring in the mine at Strandbergfeld, belonging to the Kloten company, which are deposited in the

* *Stahl und Eisen*, vol. iv. pp. 307–323.

same curious manner as at Grängesfeld, but which are occasionally much richer in phosphorus :—

	Per Cent.	Per Cent.	Per Cent.
Ferric oxide	70·88	77·44	65·61
Ferrous oxide	22·84	9·18	20·34
Manganous oxide	0·11	0·09	0·15
Lime	1·94	4·10	6·11
Magnesia	0·65	1·14	0·65
Alumina	1·02	1·87	1·07
Phosphoric acid	1·200	2·338	4·411
Silica	1·85	3·64	2·63
Sulphur	0·004	trace	0·011
	100·494	99·798	100·982
Equivalent to—			
Iron	67·07	61·34	61·74
Phosphorus	0·524	1·021	1·924

The ore which has been delivered in Upper Silesia from this mine contained from 58·5 to 67·87 per cent. of iron, and from 1·0 to 1·56 per cent. of phosphorus.

The iron-ore deposits in the province of Norrboton occur in a reddish gneiss. In the Gellivara district the total length of ground in which the presence of ore can be traced is about 5900 metres, while the breadth varies from about 1780 to 2970 metres. The ore is chiefly magnetite, which is so strongly magnetic, that it was fonnd impossible to work with the magnetometer. Red hæmatite occurs only as lumps in the magnetite, though occasionally the masses are of considerable size, and it is noticed that, in this latter case, the hæmatite is surrounded by a mass of ore which changes gradually from hæmatite into magnetite, and that there are no sharp limits between the two. This layer is sometimes 1 to 2 feet thick. There is no difference in the percentage of phosphorus contained in the hæmatite and in the magnetite, although apatite can be discovered in this latter, but not in the former. Of forty-one assays, twenty-six showed over 70 per cent. of iron, thirteen from 60 to 70 per cent., and only two under 60 per cent. Twenty-eight assays showed a percentage of phosphorus varying from 0·104 to 1·727, with a mean of 0·515; three gave from 0·05 to 0·1 per cent., and ten showed from 0·011 to 0·05 per cent. The percentage of sulphur is inconsiderable; nine assays gave from 0·05 to 0·18, and twelve samples contained no sulphur whatever. Manganese is present in very inconsiderable quantities, but four assays showed 0·45 to 1·91 per cent. of titantic anhydride.

Fifty-eight miles north of the Gellivara district are the Kirunavaara and Luossavaara hills, which are composed entirely of iron ore. The former

rises to a height of about 700 feet above the level of a lake at its foot, and is calculated to contain above this level 260,500,000 tons of ore; every metre deeper would yield 1,510,000 tons. The ores contain from 62 to 73½ per cent. of iron, and it is curious that the sample which contained the least iron contained the most phosphorus, viz., 2·709 per cent. The highest part of the hill is formed of the most highly phosphoric ore, the phosphorus decreasing with the height of the hill. The percentage of sulphur varies from 0·03 to 0·15, but even with the microscope no pyrites can be discovered. The Luossavaara hill rises to a height of about 150 feet above the level of the lake, and has a length of about 1400 yards. It is calculated that it contains above the lake level 27,656,000 tons of ore, and that each metre of increased depth would yield 239,000 tons. Assays of the ore gave 69·5 to 73·0 per cent. of iron; lime, from 3 to 10 per cent.; phosphorus, from 0·01 to 0·82 per cent.; and sulphur, from 0·03 to 0·09 per cent.

Influence of Charcoal upon the Amount of Phosphorus in Pig Iron.—It has long been noticed that the amount of phosphorus in Swedish pig iron, produced in charcoal furnaces from ores containing a very small percentage of phosphorus, is greater than that which corresponds to the amount in the ores. In order to obtain exact figures of the amount of phosphorus that can be transferred from the charcoal to the pig iron, Dr. Tamm * has made phosphorus determinations of general samples of blast furnace burdens from six furnaces, also phosphorus determinations in the resulting pig iron, and, finally, in the pig iron obtained from the same compositions by the dry assay. The results were as follows:—

Blast Furnace situated in	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Upland . . .	117·3	Cold	52·35	0·002	0·007	0·014	0·004	0·010	0·009
Upland . . .	96·5	80°	51·30	0·002	0·007	0·014	0·004	0·010	0·010
Vestmanland .	110·6	250°	54·36	0·002	0·009	0·017	0·006	0·011	0·010
Dalarne . .	88·5	300°	47·03	0·005	0·011	0·019	0·010	0·009	0·010
Vermland . .	117·1	250°	48·04	0·005	0·013	0·026	0·010	0·016	0·014
Vermland . .	97·8	200°	50·37	0·006	0·013	0·021	0·012	0·009	0·009

Column I. exhibits the amount of undried charcoal consumed, in parts per 100 parts (by weight) of pig iron produced; II. the temperature of the blast in degrees centigrade; III. the pig iron in per cent. of burden as obtained in the blast furnace; IV., V., and VI. give, respectively, the percentage of phosphorus found in the burdens, the pig iron obtained by

* *Jernkontorets Annaler*, vol. xxxvii. p. 70

crucible assay, and the pig iron produced in the blast furnaces; VII. gives the percentage of phosphorus in pig iron calculated from the amount of phosphorus and percentage of iron in the burdens; VIII. gives the percentage of phosphorus in pig iron originating from the charcoal; lastly, IX. gives the calculated percentage of phosphorus in undried charcoal.

From these results it will be seen that about 0·01 per cent. of phosphorus in the pig iron may be safely considered as coming from the charcoal.

The Composition of Swedish Blast Furnace and Bessemer Converter Gases.—The results of an elaborate series of investigations on the nature of the gases issuing from charcoal blast furnaces have been recently published by Professor Tamm.* They are arranged in tabular form, and in each case the nature and composition of the charge is appended.

The following is a characteristic result:—For every 100 lbs. of pig iron produced there passed into the waste gases

Carbon	69·7 lbs.
Oxygen	131·0 ,,

As much as 56·9 lbs. of the oxygen were derived from the ore, the charcoal, and the limestone; the remaining 74·1 lbs. came from the blast, and had combined with 55·6 lbs. of carbon to form carbonic oxide.

The 69·7 lbs. of charcoal consumed for every 100 lbs. of pig iron produced contained 66·6 lbs. of carbon, 55·6 of which combined with the oxygen of the blast, 4 lbs. passed into the reduced iron, and there remain consequently 7 lbs. for direct reduction purposes.

From the general nature of the results it is evident that the relative ratio of carbonic anhydride to carbonic oxide increases with the degree of oxidation of the ore, while there is a simultaneous decrease in the amount of carbon consumed. It also appears that with smaller furnaces the amount of charcoal required for similar charges is greater than in the case of larger ones.

The results of analyses of the gases in the neighbourhood of the tuyeres are also given.

The author also analysed the gases escaping from Bessemer converters, the samples being extracted from the converter by means of a wrought-iron tube 16 feet long and 1 inch in internal diameter, having bent at right angles 18 inches from one of its ends, and a fire-clay tube attached to this bent part.

At the commencement of the blow the short part of the tube was

* *Jernkontorets Annaler*, vol. xxxv. p. 462.

placed inside the mouth of the converter, and after a short period the end of the tube was closed by a wooden plug, and a sample of the gases collected in a glass tube in the ordinary manner.

The experiments showed that the oxygen present in the gases at the commencement of the blow rapidly diminishes, the carbonic anhydride existing in variable quantities; at the commencement of the blow carbonic oxide begins to form. The quantity of this gas first increases slightly, and then diminishes again at a later stage when but little carbon is left in the iron. The behaviour of the carbonic anhydride is exactly the reverse of that of carbonic oxide. The oxygen of the blast exists only in small quantities in the escaping gases at the commencement of the blow, the greater portion having been consumed in forming the slag by combustion of silicon, manganese, and iron. After the carbonic oxide begins to form, the oxygen in the gases increases to such a degree, that, at a later period of the blow, more oxygen was actually found in the escaping gases than had entered in the blast, which shows that during the period of the lively combustion of the carbon a part of the slag is again reduced. Towards the end of the blow, when the iron has become poor in carbon, the quantity of oxygen in the gases decreases again as compared with the amount entering in the blast. The following are the results of some analyses:—

Name of Works.	Pig Iron.					Bessemer Metal.		
	As Graphite.	Carbon per Cent. combin'd	Total.	Silicon per Cent.	Manganese per Cent.	Carbon per Cent.	Silicon per Cent.	Manganese per Cent.
Långshytten	4·12	0·20	4·32	1·10	0·63	0·25	0·02	0·03
Bångbro	2·24	2·45	4·69	0·97	1·66	0·10	0·02	0·06
Nykroppa	2·86	1·50	4·36	0·98	1·73	0·07	0·02	0·04
Vestanfors	1·68	2·50	4·18	1·92	4·83	0·22	0·04	0·09

As will be seen from the accompanying table, an approximate computation was made as to the ratio borne by the period preceding the formation of carbonic oxide (1) to the remaining portion of the blow (2).*

For every 100 lbs. of blast there were present in the gases the following quantities of oxygen and carbon:—

* *Jernkontorets Annaler*, vol. xxxv. p. 469.

Name of Works.	Oxygen in Pounds.				Carbon in Pounds.			
	Ratio of 1st Period to the 2d.	During 1st Period.	During 2nd Period.	Mean for the whole Blow.	During 1st Period.	During 2nd Period.	Mean for the whole Blow.	Ratio of Weight of Oxygen to Weight of Carbon.
Långshyttan	1:0·6	10·8	23·7	16·0	3·0	15·4	8·0	2:1
Bångbro	1:0·5	9·3	22·7	16·0	1·7	14·3	8·0	2:1
Nykroppa	1:0·3	17·5	20·9	19·9	0·8	13·7	9·8	2:1
Vestanfors	1:0·4	8·0	16·4	13·0	2·8	11·1	7·8	1·67:1

At the Vestanfors no gas was withdrawn during the first two minutes of the blow, so that the amount of oxygen given in the table is probably too low, and that of carbon too high.

The author concludes that in Swedish Bessemer Works, on the average, 400 cubic metres of air at 0°C. and 760 mm. pressure are used for every 1000 kilogrammes of ingot iron produced by the converter.

The Absorption of Carbonic Oxide by Copper Protochloride.—Professor Tamm, in the course of his investigation on blast furnace gases,* discovered a serious error to which the estimation of carbonic oxide by ammoniacal cuprous chloride is subject. The absorption in this case does not depend on a true chemical combination, but is only of a mechanical nature. It follows that the absorptive power of the reagent is modified by temperature and pressure, and can never be complete in the presence of other gases. Again, a solution which, by being used in a former analysis, has taken up carbonic oxide, will yield up some of it to a fresh sample of gas which contains no carbonic oxide, or a smaller quantity than that operated on before. To prove the correctness of his observation, the author treated a sample of blast furnace gas in an Orsat apparatus till all the action of the cuprous chloride had ceased. The gaseous residue was then removed and replaced by an equal volume of pure nitrogen. The nitrogen, on being brought into repeated contact with the solution of cuprous chloride, showed an increase of volume. That this increase was not due to the tension of ammoniacal vapours was proved by an analogous experiment with fresh cuprous chloride; here no change was observed. The increase in volume, in the former case, would be equal to the quantity of carbonic oxide which, in the previous gas sample, had remained unabsorbed, and added to it would give the true

* *Jernkontorets Annaler*, vol. xxxiv. p. 613.

volume of carbonic oxide. The author recommends this as a mode of correcting the analysis, but prefers to reduce the sources of error to a minimum by operating at a temperature of 0°C, and renewing the copper solution as often as possible. He also suggests the use of two absorbing vessels containing the reagent, one to be used first to absorb the greater part of the carbonic oxide and the other for the removal of the last portions. The estimation of carbonic oxide by combustion with air or oxygen is, however, a method greatly to be preferred.

Improvement in the Process of Pouring and Casting.—Carl August Caspersson of Forsbach has obtained an English patent for an improvement, the object of which is to procure ingots and castings free from blowholes.* In order to obtain this result the metal falling into the mould is divided into a great number of small streams, and by this means the gases contained in the metal are enabled to escape. A vessel is used, called a collander funnel, which is furnished with openings in the bottom, and into this the metal is gradually run before passing into the mould which is placed immediately beneath it. The finer the perforations in the funnel, the better will be the result obtained, provided always that they are not so small as to cause them to become clogged up by the metal under treatment. To prevent the oxidation of the metal while tapping, some arrangement must be made to exclude the air from the inside of the mould, and this end is attained by placing a loose cover on the mould, having one opening through which the metal can be poured, and another to permit of the escape of gases; or the funnel may be provided with a flange or collar which rests on the mould and tightens round the collander funnel; this latter consists of a conical vessel of sheet-iron lined inside with fire-resisting material, and perforated at the bottom with a large number of fine openings.

Rolling Mills in Sweden.—Rolling mills have during the last few years been set up in Sweden, where the blooms are, without reheating, rolled directly into bars, which then serve partly for the manufacture of rod and wire iron, and partly for the manufacture of cast steel; but in general the blooms are, after being shingled, allowed to cool completely before being reheated in separate furnaces. When the latter process has been effected, the iron is drawn in the usual manner by means of hammers or rolls. The blooms are not piled, but each one is, at the smaller works, reheated by itself in drawing hearths; at all large works, however, gas reheating furnaces are now employed. The furnaces are very long, and the materials are placed in them cold at the end which is

* *The London Iron Trade Exchange*, May 24, 1884.

furthest from the fireplace, and are brought forward by degrees; as the materials at the other end become hot and are taken out, the cold ones advance to the firebridge, where they attain their proper heat. Thus, as soon as the removal of the hot blooms at the one end has caused an empty space at the other, it is at once filled with cold materials, and thus the process goes on uninterruptedly.

The Bångbro Iron and Steel Works are the largest of their kind in Sweden. They are situated on the Frövi-Ludvika branch of the Central Swedish Railway. The foundry has been recently entirely remodelled and modernised, and is now equal to any demand that may be made upon it. The works are planned on the Belgian principle, and attached are cottages for the workmen, and a school-house, where gratuitous education for the children of the employés is provided at the cost of the company. To these works belong the famous iron mines of Ställberget, situated some ten miles from the Bångbro Works, but close to the Frövi-Ludvika Railway; from these mines excellent iron ores, free from sulphur and phosphorus, are obtained. The company also own others on the same line of railway, which all produce good ores for Bessemer or other purposes. The work consists of two blast furnaces, two more being under construction, three ore-roasting furnaces, an apparatus for the drying of charcoal, a Bessemer plant of two converters, a gas generator, besides machinery for casting and for making iron moulds and effecting the repairs necessary in the works. There are also furnaces for smelting copper, of which a small quantity is returned every year. A network of railways connects the different departments of the establishment, which, again, is directly connected with the whole of the Swedish railway system at the Bångbro terminus of the Frövi-Ludvika Railway. The works are capable of turning out nearly 10,000 tons of Bessemer pig per annum, besides 7200 tons of Bessemer ingots. From the mines belonging to the works there are raised yearly, at Stälöbergs, about 9500 tons of ore; at Elf, 2100 tons; at Carlands, 2100 tons; at Hellströms, 2100 tons; and from other towns in which the company has an interest about 4200 tons—in all about 20,000 tons of coal per annum. The result of the blast-furnace operations during 1882 were approximately as follows:—Bessemer pig made, 9000 tons; number of shifts at blast furnaces, 728; average quantity of charcoal consumed in twenty-four hours, 94½ loads; average quantity of pig iron made, 23½ tons; average quantity of lime added per cwt. pig iron, 9·11; percentage of iron in ores, 51·52; pressure of blast in lines of mercury, 16·20; temperature of blast, from 250° to 300° C. The results of the Bessemer operations during 1882 were:—Finished Bessemer ingots about 6000 tons; number of shifts, 342; average number of blows per shift, 5·93; average

make of ingots per shift, $15\frac{1}{2}$ tons; Bessemer pig, 1·130; spiegeleisen, 0·026; manganese, 0·005; total, 1·161. There was returned of steel per cwt. pig iron expended, 87·13 per cent.; and of scrap, 2·15 per cent.; while there was wasted, 1·36; and oxidised, 9·36 per cent. = 100. The dimensions in feet of the furnaces are as follows:—Height from the ground to charging plates, 55; height of the boshes, 15. The furnaces are capable of holding 52 charges of eight barrels = 2620 cubic feet; and the roasting furnaces 104 1-6th tons, roasting on an average $35\frac{1}{2}$ tons per shift. The dimensions of the converters in feet are as follows:—Height, 8·15; diameter, 5·00; ditto, in the bottom, 3·70; ditto, at the top, 1·00.*

The Domnarfvet Iron and Steel Works.—The Domnarfvet Iron and Steel Works are situated in Dalarne, on the Stora Kapparbergs Bergslag, the greatest iron deposit in the country. They were founded in 1872, at a cost of £255,000, and commenced working in 1878; and the Swedish iron industry furnishes no example of a development so rapid as that of this concern. The works are situated on the Dalelfen watercourse, from which the motive power is obtained. The fall at the works is 18 feet, but as this is not sufficient, a tunnel 1000 feet long and 20 feet wide has been constructed from above the waterfall. It supplies 3000 cubic feet of water per second, and represents a force of 5000 h.-p. According to the plan of foundation, it will be possible for the works, on an emergency, to turn out about 42,000 tons of pig iron, bars, rails, plates, &c., per year. The works embrace a building containing the blast and roasting furnaces; another containing the Bessemer converters, directly connected with the former; another, 45 feet by 550 feet, in which is situated a Siemens-Martin furnace; a reheating furnace, next to which are the blast engines; engineering plant; a rolling-mill, 75 feet by 550 feet, containing the necessary machinery and hammers; and works, 45 feet by 550 feet, for the finishing of manufactured goods. The buildings contain 3 blast furnaces, 3 roasting furnaces, 2 regenerative furnaces, 2 Bessemer converters, 1 10-ton travelling steam-crane, 6 blowing machines for the Bessemer works, several generators, 9 Lancashire hearths with 2 crushing hammers, plant for the manufacture of plates, rails, bar iron of smaller and heavier dimensions, girders, &c.; 13 reheating furnaces; 2 Siemens-Martin furnaces, 8 gas generators, 1 pair of plate shears, 3 bar iron shears, 3 circular saws, besides pumps, turbines, &c. The process of making pig and other iron is similar to that followed at most Swedish works, and the fuel chiefly used is charcoal, obtained from the company's own forests. There are employed at the works about 500 persons, and the

* *Iron and Coal Trades' Review.*

wages paid amount to £23,000 a year. During 1882 there were manufactured—Pig iron, 11,000 tons; bar and fine iron, 10,000 tons; Bessemer steel, 3000 tons; Siemens-Martin steel, 3000 tons; plates, 300 tons; castings, 280 tons. The iron and steel sold during 1882 realised about £150,000. The greater quantity was exported to England and America, where the metal is used for making best steel articles.

The Determination of Phosphorus in Iron.—In comparing the results obtained by various methods employed for the estimation of phosphorus in iron, Professor A. Tamm * is of opinion that the simple molybdate method, when done carefully, gives as good results as any of the others, but states that the manner in which the solution of the iron is effected is of the most vital importance, and he compares the following methods of solution with one another.

A. Dissolve in nitric acid of 1·20 spec. grav., using 12 c.c. for each gramme of iron; boil slowly on a hot plate till the solution is complete, then boil rapidly and evaporate to dryness. When dry heat at a temperature of 200° c. for about an hour, take up with hydrochloric acid of 1·19 spec. grav. using 6 c.c. for each gramme of iron. Evaporate rapidly to dryness, redissolve in hydrochloric acid, and boil off as much of the acid as possible without allowing any of the iron salt to become dry, then add an equal quantity of water and filter the silica.

B. Dissolve in nitric acid of 1·20, evaporate to dryness on a water bath, take up with 5 c.c. of a mixture containing three parts hydrochloric acid (1·12) and 2 parts nitric acid for every gramme of iron, dilute with 4 c.c. of water per gramme of iron and filter.

C. Dissolve in nitric acid as in B, evaporate till the solution thickens, add hydrochloric acid of a spec. grav. of 1·19 (6 c.c. for each gramme of iron), evaporate till dry and then heat for an hour to at least 200°, dissolve in hydrochloric acid, boil off the excess of acid, and filter.

D. Dissolve as in C, but with this difference, that after the addition of hydrochloric acid the evaporation is not continued to dryness, but only so long as none of the iron salt becomes dry; water is then added, and the silica filtered off.

The author is of opinion that the first method (A) gives the best and most trustworthy results. Evaporating the nitrate to dryness and then heating strongly without the previous addition of hydrochloric acid is the best way to obtain all the phosphorus in a state in which it can be precipitated by ammonium molybdate. It is not absolutely necessary to evaporate till dry a second time as far as phosphorus is concerned, but

* *Jernkontorets Annaler*, 1884, pp. 1–23.

the silica is more easily separated by filtration afterwards than it would otherwise have been.

The method B, which was the one formerly employed in Sweden and used by the author himself until March 1881, only gives about two-thirds, or at the utmost three-fourths of the total quantity of phosphorus in the iron, so that all analyses published by him before that period were proportionately too low.

With regard to method C he shows that although it occasionally gives as good results as A, yet it is not nearly so trustworthy, as it frequently shows only about nine-tenths of the phosphorus which is really present; and in order to obtain good results by this method he is of opinion that the solution, after evaporation to dryness, should be heated up to about 300° C., but this temperature is not easy to obtain on an iron plate, and is dangerous to the beaker.

Only one comparative analysis was made by method D, and this one gave most unexpectedly a result which was quite as good as that obtained by method C; but the author does not recommend the method, because the silica is obtained in a state in which it is apt to stop the pores of the filter-paper, and the filtration consequently takes twice as long; and, further, he believes that the results are, as a rule, certainly too low.

With regard to the question as to why the phosphorus remains in solution, the author considers that it is owing to the formation of organic acids due to the solution of the "combined" carbon in nitric acid, and that these are afterwards decomposed on heating the evaporated solution to 200° C, or upwards; and as a proof he remarks that white iron treated by method A gives molybdate precipitates of a pure yellow colour, but if treated according to method B, C, or D, the precipitates are of a more or less dark-brownish tint, due to the presence of organic compounds.

STATISTICS.

Production of Iron Ore in 1882.—According to official statistics,* there were, during the year 1882, 663 iron mines in Sweden, 459 of which were actually working. The production of iron ores was 20,961,327 centners, together with 43,447 centners lake and bog ores. The number of persons employed amounted to 6183. The greatest production of ore was in the following districts:—

	Ctr.
Orebro	5,622,245
Kopparberg	5,256,464
Vermland	2,673,890
Vestmanland	4,725,875
Upsala	1,158,180

* *Stahl und Eisen*, vol. iv. p. 124.

In the last-mentioned district the twelve mines belonging to the Dannemora Company produced 796,624 ctr. The number of steam engines at the mines was 106, or two more than in the previous year.

Pig Iron.—The production of pig iron in 1882 was 9,385,256 centners, or about 750,000 centners less than in 1881, and 170,000 centners less than in 1880. 185 blast furnaces were in blast, twelve less than in 1881. The average production of one furnace was thus 50,737 centners. The largest producers of pig iron were the following districts :—

	Ctr.	Furnaces.
Orebro . . .	2,360,000	50
Kopparborg . .	1,935,400	39
Vermland . .	1,473,841	26
Gefleborg . .	1,342,800	22

The greatest production was attained by the Domnarfoet Works, near Falun, from two blast furnaces—261,483 centners. The production of castings increased from 324,675 centners in 1881, to 352,944.

Wrought Iron.—The production of wrought iron amounted to 6,103,895 centners. 266 works with 773 hearths and furnaces were in operation; but there were only seven puddling furnaces in the whole of Sweden. The wrought iron works were ten less than in the previous year; on the other hand, the hearths and furnaces have increased by 28. The increase in the production amounted to 276,540 centners. In this branch the Orebro district again stands first with a production of 1,228,804 centners, from forty works with 139 hearths and furnaces. Then follow Vestmanland and Kopparberg, each with a production of nearly a million ctr., as in the previous year the Uddeholms Works produced the largest amount of wrought iron in the country, the production amounting to 271,038 centners, against 235,065 in 1881.

Steel.—The production of steel in Sweden has regularly increased during the last five years, as may be seen from the following figures :—

	Ctr.
1878	609,724
1879	672,390
1880	924,072
1881	1,228,651
1882	1,463,120

The production of Bessemer steel in 1882 was 1,114,117 centners from fifteen works. The total production given above also includes 315,354 open-hearth steel, 15,710 centners cement steel, 4886 centners cast steel,

and 5650 centners puddled steel. Only 139 centners of shear steel were produced, and the Uchatius steel seems to have entirely disappeared. Avesta (see this Journal, 1883, p. 864) appears this year for the first time as a producer of Bessemer steel.

Iron and steel were further treated in 156 works, producing 1,021,211 centners manufactured products. The Swedish ironworks in 1882 employed 19,477 persons, 228 more than in the previous year, and eighty steam engines.

UNITED STATES.

CONTENTS.

I.—*ORES AND FUEL.*

The Brown Hæmatite Ores of Central Pennsylvania.—At a meeting of the Engineers' Club of Philadelphia, E. V. d'Invilliers read a paper on the characteristics and mode of occurrence of limonite in Central Pennsylvania, taking for his field of illustration the Lower Silurian limestone valleys of Center County. The anticlinal structure of these valleys, and the great erosion the rocks have undergone, have influenced the position and character of many of the present ore-deposits. There are three varieties of ore: the wash and lump hæmatite of the Barrens, the true limestone "pipe-ore," and an intermediate transition variety. The first is always associated with sandy magnesian beds, and is composed of rounded ore and flint balls and tough barren clay, being secondary or derived deposits of irregular shape. They have been tested to a depth of 100 feet, and contain from 45 to 53 per cent. of phosphorus. The cost of mining is about $1\frac{1}{2}$ dollars per ton. The transition variety was assigned a position in the formation from 3500 to 5000 feet below the slates. The ores are characterised by a more calcareous clay. They are compact, amorphous, liver-coloured ores, containing from 40 to 49 per cent. iron, and from 0·115 to 0·365 per cent. phosphorus. The pipe ores usually occur in the limestones, higher than either of the other two, but in this district below the 400 feet of Upper Trenton beds. These ores occur between parallel walls of limestone. The deeper beds show the repeated occurrence of crystals of iron pyrites in all stages of alteration. The ores occur at great depths, and show from 45 to 53 per cent. of iron, and from

0·1 to 0·185 per cent. of phosphorus. The quartz grains accompanying them are rarely water-worn, and the clay is very calcareous and easily washed. The cost of mining these ores varies from 90 cents to $1\frac{1}{4}$ dollars per ton.

The Bedford Cannel Coal.—In a paper read before the Ohio Institute of Mining Engineers, E. Orton calls attention to a coal seam in the hills of Southern Jefferson and Northern Bedford townships, Coshocton County, Ohio. It is most widely known as the Bedford Cannel, the largest tracts of it being found in Bedford township. It is the largest and probably the best body of cannel in Ohio, but its remoteness from the railroad has prevented its reputation or use from extending far.

The area of ground covered by the coal is not large, being about 16,000 acres. The area of workable cannel is probably not more than 300 acres. At Moore's Bank, which was formerly worked on a large scale, the cannel is about 6 feet thick, with about a foot of poor bituminous coal above it. Eastward from Moore's Bank, the cannel thins down to a foot or so, included between 18 inches of bituminous coal above and below. The seam is here not worth working. After passing Flint Run, the cannel increases in thickness, until, on the hills of Simmons Run Valley, it attains a thickness of 5 feet, with 3 feet of good bituminous coal as a roof. The largest body of fine cannel lies on the southern edge of Jefferson township. Nearly every farmer has opened the coal seam on his lands, and many exposures of the cannel coal are found. In most of the area it figures as a thin stratum, 6 to 12 inches thick, with common coal above and below. When, in the spots of valuable ground, the cannel becomes thicker, the under coal disappears, leaving the cannel resting on a stiff fire-clay floor.

From time to time a market has been opened for the coal, but the distance from the railway is twelve miles, and this, of course, makes it expensive. It has been tested in New York, and has been praised as a most excellent article. There are three grades of the coal. The middle part of the seam is the best, and the bottom next. The top is the most valuable for making oils, though it contains so high a percentage of ash as to be often slaty. The amount of sulphur is moderate. An analysis of the Bedford cannel by Professor Lord gave the following results:—

Moisture.	Hydrocarbons.	Fixed Carbons.	Ash.	Sulphur.
2·35	47·05	37·00	13·60	2·33

The owners of this cannel are mainly farmers. The deposit, valuable as it is, is doomed to be inactive until railroad communication opens it up to civilisation. The Mount Vernon, Coshocton, and Wheeling Railway is, however, pushing rapidly forward, and in a very short time trains

will be daily passing within two miles of the best of the cannel. Under such circumstances it is certain to be opened up.

The Coal Deposits of Alabama.—The extensive deposits of coking and cannel coal in the Warrior coalfields of Alabama are beginning to attract wide attention. This field is stated to be almost inexhaustible, and will soon be a formidable competitor for the coal supply of the West, and, on the seaboard, will even come into serious competition with the present supply from Pennsylvania, West Virginia, Maryland, Australia, and England. The deposits in the Warrior basin will, it is thought, drive all other coals out of Mobile and other Gulf ports.

The Value of Petroleum as Fuel.—As great amounts of money, time, and energy are now being expended in attempts to introduce vapourised petroleum for fuel for metallurgical purposes, and as these attempts are made blindly without ascertaining whether there is any probability that a given amount of work could be done as cheaply with petroleum as with coal, H. M. Howe * has written an article with the view of putting engineers contemplating these attempts on their guard, and of pointing out to them how exceedingly small is the chance that petroleum can compete with coal as long as the present relation between the prices of the two continues. There cannot be the slightest doubt that many of the statements that have appeared in the technical journals during the last year, as to the consumption of petroleum in accomplishing a given result, have been grossly inaccurate. The author does not believe that petroleum can replace coal for any ordinary or extended metallurgical purpose, until the cost of 300 gallons of petroleum shall be the same as that of a ton of coal. Such conditions may exist in the immediate neighbourhood of petroleum fields and far removed from coal, as, for example, on the west coast of South America in certain probably very limited regions, or at certain places in India. The author knows of no place in North America where, the use of petroleum having been found economical, the facts have been carefully and systematically investigated by disinterested engineers. On the other hand, there are important establishments where its use has been thoroughly tested on an enormous scale for many months consecutively, and where the ratio of the price of petroleum to that of coal is comparatively low. In these its use has been found vastly more costly than that of coal, even after making all possible allowances for its undoubted advantages of saving in handling and repairs.

* *Engineering and Mining Journal*, vol. xxxvii. p. 483.

Natural Gas in the Production of Iron.—At the Cincinnati meeting of the American Institute of Mining Engineers, Capt. W. R. Jones made an interesting statement in regard to the use of natural gas at the Edgar Thompson Steel Works. These works own a gas-well at Murraysville, about twelve miles from their mill. From this well an 18-inch pipe is laid to the works. At the well the pressure is about 120 lbs. to the square inch. This is reduced in transmission to the works to 60 lbs. The gas is used in the boilers, of which there are 48. Sixteen volumes of air are required to properly consume one volume of gas. The use of the gas at these boilers has enabled the works to dispense with 82 men.*

Improved Gas Furnace.—W. F. Durfee of Bridgeport, Connecticut, and T. Egleston of New York, have patented an improvement in gas furnaces,† which is intended to facilitate the introduction of air, steam, or other vapour or gas into the heating or melting chamber of the furnace at certain stages of the operations, when such an introduction and distribution are desirable. The main point of the improvement consists in two long tubes placed outside the furnace; into these tubes air or other gas may be passed, which would then enter the furnace through a series of small tubes in connection with and at right angles to the two large external ones.

Improvement in the Chequer-Work of Regenerative Furnaces.—The improvement which has been patented by W. Swindell of Allegheny, Pennsylvania, consists in making the bricks conical or pointed at their right and left ends, so as to obtain an increased surface of irregular form which breaks or divides the currents of gas and air, and affords a larger absorbing or radiating surface. It is claimed that the force of the currents of air and gas is retarded in a less degree, and that the bricks are not so liable to be cut and injured by the currents of heat.‡

The Prospective City of Sheffield, Alabama.—A syndicate of New York and Atlanta capitalists have bought 3000 acres of land on the Tennessee River, Colbert County, Alabama, with the intention of founding a city and making it the iron-manufacturing centre of Alabama, the special aim being to lessen the cost of iron with a view to attracting manufacturers.§ A new railroad of eighteen miles in length has been

* *Mining and Scientific Press*, 1884, p. 223.

† *The Iron Age*, May 15, p. 33.

‡ *Ibid.*, April 24, p. 5.

§ *Ibid.*, May 15, p. 29, and June 26, p. 1.

completed, and contracts have been made for the erection of three furnaces and a water-works. The prices realised for sales of land by the syndicate have been so high that the stock of the investors has increased in value 500 per cent. Sixty miles south of the proposed city are extensive coal-fields with which it is to be connected by a railway, and within thirty miles are important deposits of brown hæmatite, with 49·20 to 57·60 per cent. of metallic iron and 0·12 to 0·47 per cent. of phosphorus.

II.—*BLAST FURNACE PRACTICE.*

The Charcoal Blast Furnaces of South-Western Virginia.—A typical blast furnace of this region consists of a stone stack, 30 to 40 feet in height, and having an internal diameter at the boshes of from 8 to 10 feet. The furnaces make from 5 to 10 tons per day, with a consumption of charcoal of from 130 to 160 bushels per ton of iron produced, each bushel representing a weight of about 20 lbs. The following results were obtained from working a furnace with a 9-feet bosh, and they are believed to be a fair average record :—In five months 1090 tons of pig iron were made, with a consumption of 152,844 bushels of charcoal, 5,200,160 pounds of raw iron ore, and 320,094 lbs. of flux. This is equivalent to 140·2 bushels of charcoal, 4770·7 pounds of ore, and 293·6 pounds of limestone per ton of iron made. The ordinary charge of the furnace was forty boxes of ore = 800 lbs., one box of limestone = 54 lbs., and $25\frac{3}{4}$ bushels of charcoal = 512 lbs. The usual practice is to charge with the limestone aluminous clay in such varying quantities as occasion seems to require. The hearths, crucibles, and boshes are of dressed sandstone, and the walls are lined with shale. The crucibles are either square or round, measuring 24 to 30 inches at the bottom, and from 30 to 36 inches at the top, their height being 5 feet. The boshes are quite flat, having a batter of 9 inches to the foot, and the walls slope regularly from the top of the boshes to the throat. The tuyeres are placed about 27 inches above the bottom. One furnace of a much more modern type has been erected in the district, and this has a height of 42 feet, with a diameter at the boshes of 11 feet. Hot blast is used, and the output has reached 35 tons per day. The basis of a charge is 700 lbs. of charcoal. The lump ore before being charged into the furnace is first roasted with furnace-gas, and then passed through a crusher.*

New Blast Furnace Plant.—A new plant is about to be erected on

* *The Journal of the United States' Association of Charcoal Iron Workers,* April 1884.

the property of the Dayton Coal and Iron Company, thirty-eight miles north of Chattanooga on the line of the Cincinnati Southern Railway. A coal seam, 4 feet thick, runs through the property, the coal being of a very good caking variety. There will be two blast furnaces, 70 feet high and 20 feet diameter at the boshes, with six Whitwell stoves, 21 feet in diameter by 60 feet high. The stack for the stoves has a flue 8 feet in diameter and 160 feet high. There will be twenty-four boilers, 46 inches in diameter and 34 feet long, fitted with two 16-inch flues. The boilers are to be made of steel having a tensile strength of 50,000 lbs. The stacks for the boilers will be two in number, each 125 feet high, and 8 feet in diameter. There will be five blowing-engines, the steam-cylinders of which will be 3 feet in diameter, and the blowing-cylinder 7 feet, with a 5-feet stroke. The capacity of the plant is estimated at 70,000 tons of pig iron per annum.*

The Weimer Regenerative Hot-Blast Stove.—The Weimer stove consists of two or more regenerative chambers placed one above the other, through which the gases pass in but one direction. The gas from the blast furnace enters and is ignited in the lower combustion chamber, then passes up through a series of square flues, in firebrick masonry, into the second combustion chamber, where heated air enters by a flue in the brickwork, and cold air is admitted through valves in the casing, to secure a more perfect combustion of the gases. The same is repeated in the third combustion chamber. The gases then pass out of the chimney that surmounts the stove.

The stoves are formed of an iron casing inclosing a mass of firebrick work, made in alternate layers of mitered bricks and bricks in the form of Greek crosses. The arrangement of these bricks admits of the formation of a substantial dome-top for the combustion chambers without the necessity of using arched brick. After the stove has been thoroughly heated by the gases passing through it, the damper in the draught-stack is closed, and blast from the blowing engine enters the stack by the cold-air pipe, and, passing down through the square openings in the regenerative chambers, becomes thoroughly heated, and leaves the stove at the bottom. For this novelty in the construction of regenerative hot-blast stoves, patents have recently been issued to the Weimer Machine Works Company of Lebanon, Pennsylvania.†

New Hot-Blast Stoves.—J. F. Bennett of Pittsburg, Pennsylvania, is the patentee of a blast furnace in which an atmospheric current forced

* *The Iron Age*, May 29.

† *Engineering and Mining Journal*, vol. xxxvii. p. 459.

by a blower is raised in temperature by passing through an intermediary stove. The walls and tubes of this stove are heated by the passage, in an opposite direction, of the waste gases from the blast furnace. The invention relates to the construction of this stove, and is designed to decrease frictional resistance of the heated air passing through it, and to present a large absorbing and heating surface. The stove is provided with a short wall which serves both to divide the air-blast and to sustain the arch. It accomplishes the former by its peculiar shape, its cross-section forming a three-sided prism, of which the pointed end is turned to the inlet, and it supports the arch by presenting to the point of greatest pressure its greatest thickness.*

A new stove has also been invented by J. J. Airey of Pittsburg, Pennsylvania. The combustion chamber communicates with a series of flues arranged side by side, and running in a direction at right angles to the combustion chamber. Each horizontal flue communicates with the preceding and following flues at opposite ends only, so that the gases and products of combustion travel the whole length of each flue. This arrangement gives a large heating surface to the stove. The roof of the combustion chamber is arched, and an inverted arch is built above it. All the heating flues are also formed with a right and an inverted arch; the object of this construction being to enable the flues to resist the strains of an occasional explosion of the gas, which may take place when it is first admitted.†

Cup-and-Cone Mechanism.—F. W. Gordon of Pittsburgh, Pennsylvania, has patented an improvement for the raising and lowering devices of the cup-and-cone mechanism of a blast furnace. A cylindrical weight, which forms a portion of the counterbalance of the cone, may be raised and lowered by a hand-crank. By swinging a lock-lever a friction pad will be held against the weight with great force, and the weight will be thereby firmly retained in any position in which it may be set. If the lock lever is thrown backward, the friction pad will be free, and the weight is at liberty to be moved up or down through the crab-stand by means of the hand-crank. In the operation of charging the furnace the lock-lever is first thrown forward, and the charge is dumped into the cup. The lock-lever being next thrown backward, the weight of the charge upon the cone will cause it to descend and discharge its load. It then rises automatically to a closed position, when the lock-lever is again thrown forward preparatory to the dumping of a new charge into the cup.‡

* *The Iron Age*, July 3, p. 7.
† *Ibid.*, May 1, p. 17.
‡ *Ibid.*, July 3, p. 7.

Improved Form of Tuyere.—J. F. Harly of Kipton Station, Ohio, has patented a tuyere which consists of an annular air-tight chamber connected with two water-pipes and enclosing a passage-way or throat.* A concave valve, attached to the upper end of a straight stem, fits into this throat. The lower end of the stem is provided with a lever, by means of which the valve is raised or lowered. The blast pipe connects with the throat, and an ash-box is attached to its bottom. The blast is regulated by the position of the valve, around which the air escapes uniformly when opened.

A blast furnace, with tuyeres having adjustable discharge openings, has been patented by H. Schulze-Berge of Rochester, Pennsylvania. The water-cooled tuyere has a water-cooled sliding stopper preferably made hollow, and provided with a water inlet and outlet through its arms, which are made hollow for that purpose. The stopper is moved by a handle or lever. By sliding the stopper the size of the nozzle-opening can be adjusted so as to cause the blast to enter into the furnace at a higher or lower pressure.

Blast Furnace Torpedo.—J. M. Hartman of Philadelphia, Pennsylvania, proposes to remedy the evil incident upon an accumulation of chilled, or partially chilled, slag in front of the tuyeres, by the insertion of a small torpedo through the tuyere and firing it off in the immediate vicinity.† This will open fissures in the slag shell through which the blast can penetrate, such operation being conducted without stopping the furnace. The torpedo should, of course, be applied as soon as the presence of the crust becomes manifest. It is claimed that this method of opening air-passages into the interior of the furnace has the further advantage, that instead of cooling the furnace it starts combustion and generates heat at the very point where an increase is required.

Cost of Producing Pig Iron.—The actual cost of making a ton of iron in the Lehign Valley is estimated by Mr. M'Creath, chemist of the Geological Survey of Pennsylvania, at 20·38 dollars, the items being as follows:—Ore, 9·34 dollars; coal, 5·30 dollars; limestone, 77 cents.; labour, 2·33 dollars; incidental expenses and repairs, 2·64 dollars.‡

* *The Iron Age*, May 1, p. 17.
† *Ibid.*, March 6, p. 15.
‡ *Ibid.*, January 3, p. 19.

Tamping Drill Holes with Plaster-of-Paris.—In an interesting paper on this subject,* M. Firmstone stated that in the summer of 1881 the Glendon Iron Company, of Easton, Pennsylvania, were forced to remove the large mass of iron which had accumulated under No. 2 furnace, in order to prepare the foundation for the new one which has since taken its place. It frequently happened in drilling the holes that they were hopelessly blocked when but little over a foot deep, so that good tamping became very important. An excellent method was found to be to use plaster-of-paris mixed to the proper consistency, and poured into the holes as soon as loaded. Dry sand was mixed with the plaster to reduce the quantity required. With proper attention the tamping set in a few minutes, and no more time was required than for tamping in the ordinary way.

The shots were fired by electricity; and one advantage of this method of tamping is that any risk of cutting the wires is avoided. It was found that it was not worth while to load holes over 13 inches deep in a block 3 or 4 feet thick, because the bottom of the hole was enlarged by each shot, so that the next time it could be loaded more heavily. Three or four shots fired in this way often did as much good as a new hole twice the depth, to drill which might have taken 10 or 12 hours. The rise in temperature when boiled plaster solidifies was found, by repeated trials, to be insufficient to ignite the explosives.

III.—*MANUFACTURE OF IRON AND STEEL.*

New Steel Plant of the Riverside Ironworks, Wheeling, West Virginia.—The plant is intended for the production of soft steel suitable for the manufacture of steel nails. The pig iron will be run from the blast furnaces, which are 56 feet high, into an iron ladle which will be conveyed by a crane to a pair of five-ton converters. The Bessemer ingots will be 12 inches × 17 inches × 54 inches, and they will be transferred to the reheating furnace by a hydraulic crane, and will, after being heated, be withdrawn by the same crane, and placed on the table in front of the rolling mill. They will be reduced by the rolls to slabs of 3 inches × 15 inches in cross-section. These will be conveyed by tables placed on driven rollers to a vertical shear, which will cut them into blooms of 3 inches × 15 inches × 15 inches, and these will be rolled into nail plate and cut into nails in the usual manner.†

The Edgar-Thompson Bessemer Works at Pittsburg.‡—There are five blast furnaces, each 75 feet high, and one of 65 feet, with

* Read at the Cincinnati meeting of the American Institute of Mining Engineers.
† *The Iron Age*, April 3, p. 1. ‡ *The Ironmonger*, June 14, 1884.

a capacity of 310 tons per day. Formerly large quantities of Spanish ore was used, but its place has been taken by the Lake Superior ores, which yield on an average from 55 to 66 per cent. of metallic iron. Hæmatite is also obtained from a mine belonging to the company, which is situated 150 miles east of Pittsburg; the ore yields 45 per cent of iron, and the output is about 200 tons daily. These ores do not undergo a preliminary calcination. There are two engine-houses, in the first of which are seven engines each with two fly-wheels, having a 72-inch cylinder and a four-foot stroke, and in the second house there are eight such engines. There are several batteries of boilers, which are heated by natural gas. There are three ten-ton converters.

The blooms are cut and placed in position by means of travellers; as the bloom comes from the rolls it is received on to a hydraulic table upon which a series of automatically worked arms turn it over and place ready to be passed through the next pair of rolls. As the bloom moves forward the table descends on one side, and another rises to receive and turn it over on the other side of the rolls. Rails are cut and trimmed cold by a plain disc turning at the rate of 2100 revolutions per minute.

The Open-Hearth Steel Plant of the Chester Rolling Mills.— The *Iron Age* for May 22 gives a plan and description of the Open-Hearth Steel Plant recently started at Chester Rolling Mills, Chester, Pennsylvania. It was erected in 1881-82 by C. M. Rider, and is specially designed for the production of ingots for plates, beams, and angle iron, and also for shafts, cranks, propellers, and all castings required in shipbuilding up to 40 tons weight. One of the principal features of the general arrangement is the readiness with which large moulds for castings may be brought within reach of the ladles, and the metal from both furnaces simultaneously cast into them. The large ovens used for the preparation of the moulds are contiguous to the casting-pit, and have lifting tops similar to ovens employed in large pipe foundries. The melting furnaces are designed to permit of the removal and renewal of the ports, either wholly or partially, without cooling or disturbing the entire structure. The roof and wall overhang somewhat on the casting side, thus forming a short tap-hole, and rendering its cleaning and repairing after each tapping a comparatively easy operation. The platforms on the casting side swing on posts, and occupy different positions during the different operations of tapping, casting, &c.

The ladle-heating arrangements are designed to heat the ladles after they are prepared for casting and placed in the crane for that purpose. They are also out of the way of other operations, and can be brought rapidly into position to receive the metal from the furnaces by a single

man, and without the application of any mechanism requiring steam or hydraulic power, the arrangements being as follows:—An upright gas-pipe stands midway between the furnaces, the upper end forming a large T. Attached to each branch by hinges is a brick-lined ladle cover fitted with gas-pipes, registering with openings in the upper side of each T when the covers are lowered on the ladles, and also fitted with counter-weights sufficient to balance the covers and gas-pipes.

Improved Puddling Furnaces.—A new puddling furnace * has recently been started by the Bethlehem Iron Company, Pennsylvania. It was erected from the designs of W. Stubblebine, and differs from those of the ordinary type in an arrangement which enables the pig iron for each succeeding charge to be heated up during the working off of the preceding one. It is stated that this caused a saving of an hour in time, and of a large amount of fuel. Seven charges of 1100 lbs. of pig iron are worked off during the day, and eight similar charges during the night-shift.

R. H. Oates of Port Clinton, Pa., is the patentee of a new form of puddling furnace,† in which the puddling chamber is supported on segmental shoes mounted on rollers, with their bearings on a saddle, and arranged in a curvilinear direction. The puddling chamber being supplied with the metal, is moved backwards and forwards with a circular motion. The metal is forced from end to end, and deflected inwardly at the ends by means of diagonal corner-blocks. In this way the metal is uniformly directed backwards and forwards between the corner-blocks. At each end opening of the chamber is a vertical dividing bridge. As the bridges move with the chamber, the flames from the furnace are deflected by the varying position of the bridges, and their directions constantly changed, so that the action of the fire on the metal is uniform.

The Phœnix Iron Company, Phœnixville, Pennsylvania, are the assignees of a patent ‡ for a puddling furnace in which a fixed chimney is used in combination with a suspended flue structure. The chimney is open both at the top and at the bottom, and the flue is suspended from it by links and hooks. The flue is open at the top and at the side to communicate with the chimney and the puddling outlet respectively. Set screws, passing through fixed standards, bear against the rear of the flue structure, and by loosening or tightening them the front of the flue can be moved farther away from or closer to the puddler.

New Rotary Puddling Furnace.—A patent for a furnace of this class has been granted to H. B. Van Benthuysen, of Phœnixville, Penn-

* *Iron*, vol. xxiii. p. 222. † *The Iron Age*, April 10, p. 15.
‡ *The Iron Age*, May 1, p. 17.

sylvania.* It consists of a revolving cylindrical puddling chamber, made in the ordinary way with contracted ends having large circular openings, which are formed by double or collared rings, leaving a water space between them. The cylinder is connected at one end with the mouth of a suitable heat-generating furnace, and at the opposite end with a flue for conveying away the waste gases. In this way the flames and heat generated in the furnace pass directly through the cylinder containing the iron in process of puddling. When the puddling is completed, the chamber is removed from the furnace, to withdraw the mass of puddled iron. In order to keep the exterior of the cylinder at a low temperature, it is placed within a water jacket sufficiently large to allow ample space for a constant stream of water to circulate.

Water-Joint for Rotary Puddling Furnaces.—The Phœnix Iron Company of Phœnixville, Pennsylvania, have patented a water-joint for rotary puddling furnaces.† The improvement is specially directed to the production of a joint which will not leak, and to the maintenance of a constant supply of water in the jacket of the furnace. A substantial band surrounds, and is riveted to the outer casing of the furnace, and to this band is fitted a ring also extending around the furnace, and secured to the band by set-screws. A second ring is fitted to the first, composed of two semi-annular parts bolted together. Each part is made in two segments having a vertical and a horizontal flange, and an annular rib connected to the vertical flange by a number of cross-webs.

New Form of Open-Hearth Furnace.—C. M. Ryder of New York has recently invented a new form of open-hearth furnace, the improvement in which mainly consists in a movable hearth, by means of which it is contemplated to adapt this style of furnace to general foundry work, to facilitate repairs, and to render possible the charging-in of masses of metal too large to be introduced through the charging doors of the ordinary furnace. The hearth is bedded on an iron frame resting on wheels, and is placed on an inclined plane so as to facilitate its removal when desired. When in position it is raised to a horizontal position by means of hydraulic jacks, connected with the roof, which is a fixture.

New Method of Rolling Shaped Blooms.—The Pittsburg Steel Casting Company recently rolled in six hours 92,940 lbs. of shaped deck-beam blooms. At no time during the operation was there a longer interval than sixty minutes from the melted iron to the shaped bloom. The steel had a low percentage of carbon and a guaranteed elongation of

* *The Iron Age*, February 7, p. 9. † *Ibid.* May 1, p. 17.

23 per cent. on 8 inches. The special difficulty in rolling deck-beam shapes lies in the fact that there is 22 per cent. more reduction on one side than on the other. This new method of rolling direct from the ingot will tend to a reduction in the cost of producing shapes of all kinds. A patent has been applied for by the Pittsburg Company which will cover this process.*

Machine for Drawing Bars for Heavy Shafting.—J. S. Griffin of Cleveland, Ohio, has patented a machine for drawing iron and steel bars for heavy shafting in one continuous operation.† The bars are first cut to the proper length, and the ends are heated and reduced a sufficient distance from the shoulder to the head to allow the thickest part of the bar to be drawn clear through the dies. The head is formed to fit into a recess of a sliding carriage, in which it is locked. The carriage is then moved, and will draw the bar through the die. A left-hand chain then draws the bar through a left-hand die and again decreases its diameter. If desired, two bars can be drawn at the same time. The machine needs only to be started, and when it has drawn the bar through a die it is stopped automatically.

Prevention of Oxidation.—A novel method of producing clean surfaces on iron or steel, which renders the metal less liable to subsequent oxidation than with the ordinary finish, has been patented by L. D. York of Portsmouth, Ohio.‡ A loop or thick mass of the metal is subjected, at a high temperature, to a rapid succession of alternate bendings in opposite directions by passing it through rollers arranged so as to produce that effect. Streams of water are, at the same time, thrown on the surface, and immediately afterwards the metal is subjected to the action of reducing rollers. The chilling effect of the water detaches the scales, and the reduction in thickness and in temperature follows so rapidly that further oxidation does not occur, and by the action of smooth rollers for the reducing rolls, surfaces are produced on the finished metal which are unusually perfect. The metal, it is claimed, will be almost entirely free from the black oxide which is present on iron and steel as ordinarily rolled.

Casting of a Large Cannon.—A cannon, which when complete will weigh 212,000 lbs., and which is claimed to be the largest ever constructed in the United States, was successfully cast at the South Boston Steelworks, Boston, on May 6th. The mould was made in sections, and consisted of an exterior body of iron with a layer of sand and cement on

* *Iron*, vol. xxiii. p. 413. † *The Iron Age*, April 17, p. 7.
‡ *The Iron Age*, April 24, p. 5.

the inside six inches thick, which was covered with a composition of blacking. In the interior of the flask-shaped mould was placed the core. This consisted of a wrought iron tube, round which was placed a layer of rope, and over this a layer of sand and cement. Water was not allowed to circulate in the core during the casting, which lasted twenty-four minutes, the metal being run from three 36-ton furnaces into a mixing-pot, and thence into the mould, which will be cooled by water, both inside and out, while the metal is cooling. The casting was made 5 feet longer than the intended length of the gun.*

IV.—*PHYSICAL PROPERTIES OF IRON AND STEEL.*

Testing Machines.—The entire history of testing machines in the United States is, according to Mr. A. V. Abbot,† comprised within the last thirty years. One of the first machines was built by Major Wade for the Government in 1855; this was followed by two improved machines by Captain Rodman. At the close of the American war, Fairbanks & Company built a large machine for Colt's armoury to test up to 100,000 lbs. This is stated to be the first platform machine ever built. Other machines were constructed by this and other firms, and have for the last ten years been regular articles of commerce.

Five qualities are necessary to a successful testing machine :—

1. There must be a mechanism for producing stress up to the largest size of specimen it is required to test, and this mechanism must be sufficiently heavy and rigid to produce this stress without any undue straining of any of its parts.

2. A contrivance for accurately estimating or registering the amount of stress applied.

3. A method for recording both the stress and its effect upon the test-pieces simultaneously.

4. Such appliances as shall enable the stress to be applied in any desired manner, and to any shape of test-piece.

5. The ability of the machine itself to be easily and frequently tested.

A large verticle machine by Fairbanks is said to meet most nearly the various requirements of a general testing-machine. In this machine any desired strength up to 200,000 lbs. may be applied.

Its general construction provides for weighing the forces applied by means of platforms and levers, somewhat similar to those used in ordinary scale work, with special arrangements to reduce friction. To secure the

* *The Iron Age*, May 22, p. 5.

† *Van Nostrand's Engineering Magazine*, vol. xxx. p. 89; *Engineering and Mining Journal*, vol. xxxvii. p. 177.

direction of the pressure upon the test pieces in the axis of the machine, both ends of the piece are connected with segments of spheres moving freely in spherical sockets, which take the proper position upon the first application of the stress. Arrangements are also made, by means of wedges, to grip and hold uniformly the ends of the test pieces. The machine is arranged to test: in tension, compression, for transverse stress, for shearing, bulging, and torsion. The application of stress is automatic, and at the same time the same power gives an autographic record of the stress applied, and of any variations which may occur during the continuance of the stress, and with an instantaneous autographic record of the result at the conclusion of the test. The stress is applied by means of weights which slide upon two parallel lever beams, the one registering up to 10,000 lbs., and the other up to 200,000. By means of an ingenious electrical attachment connected with clockwork, the movement of these weights is continuous and automatic, and the registering apparatus is also controlled by the same electric current.

The Strength and Elasticity of Steel for Structural Purposes.—At a recent meeting of the American Society of Civil Engineers, a paper was read by J. Christie, on the strength and elasticity of structural steel, and its efficiency in the form of beams and struts. The various grades of steel possess such a range of physical properties, that it is impossible to consider the metal as one might treat of iron. The steels subjected to the tests described in this paper were of two distinct grades, mild and hard Bessemer steel; the hard steel having 0·036 per cent. of carbon, and the mild steel 0·012 per cent. The tensile tests were made on strips about 24 inches long, to which were clamped plates 12 inches apart. The compression tests were made on specimens 12 inches long, inserted in a tube, and the spaces between the specimens and the tube were filled with fine sand. The tests on transverse resistance were to 12 on bars of 3 inches diameter, and on solid flanged beams from 3 made inches deep.

The results of these various tests showed that the elasticity of steel and iron is practically uniform. The steel may stretch less than the iron in tension; but the steel shortens most under compression. The specimens show that the elastic limits for tensile and compressive stress for the different grades of steel are practically equal per unit of section, and the transverse resistance is approximately proportioned to the longitudinal resistance. The strength of the material indicated on tensile stress will serve as a comparative measure of the absolute strength of iron or steel; but as the transverse elasticity is practically alike, beams of iron or steel of the same length and section will deflect alike under equal loads below

the elastic limit of iron. It was stated that the experiments on direct tension and compression prove that the elastic limits of steel of any particular grade are practically equal per unit of section for either direction of stress. A similar equality is known to exist with iron. For the short struts in which failure results from the effects of direct compression, the tensile resistance of the material will, therefore, serve as a comparative measure of strut resistance. As struts increase in length, the lateral stiffness becomes a factor of increasing importance. The transverse elasticity of steel and iron do not vary much. The tendency will be for struts of steel and iron to approach equality of resistance as the lengths are increased. Mild steel will fall to equality with iron when the ratio of length to the least radius of gyration is 200 to 1, while hard steel would fall to practical equality at a point beyond the limits of practice.

Steel for Structural Purposes.—At a recent meeting of the American Society of Civil Engineers a paper on structural steel was read by E. B. Dorsey. It gave the results of his examination into the subject during two recent trips to Europe. The steel used for structural purposes is in England generally called mild steel, and in Germany homogeneous iron. Experts in Great Britain generally rely more upon physical tests and the reputation of the manufacturer than upon chemical composition. The physical requirements are stated, and the manufacturer uses his discretion as to the composition which will answer these requirements. The tendency among English engineers is to use steel still softer than has heretofore been thought best. Some large builders use nothing in their boilers over 26 tons tensile strength per square inch and 25 per cent. elongation on 8 inches. Others advise the use of steel of from 23 to 25 tons tensile strength, with the same elongation. American engineers require from 15 to 20 per cent. higher tensile strength than the English. Siemens-Martin steel is preferred by nearly all experts for structural purposes, Bessemer steel being principally used for rails. Shipbuilders are decided in their preference for Siemens-Martin steel. A much larger number of plates would be condemned of the best wrought iron than of steel. Steel can be manufactured into much heavier, longer, and wider pieces than wrought iron. Steel rivets are used on the Clyde exclusively in riveting steel. The new Forth Bridge is being built of mild steel. The use of mild steel is extending very rapidly in Europe, and has fast superseded iron for structural purposes.

Steel and Iron Girders.—Mr. C. L. Strobel, in a paper read before the Engineers' Society of Western Pennsylvania, draws the following con-

clusions:—Each of the steel girders experimented on showed a large increase in strength over the iron girder. The soft steel girders proved 22 per cent. stronger, and the hard steel girders 66 per cent. stronger than the iron girder. The greater strength of the soft steel over the iron in the specimens was fully attained and exceeded in the girders. The hard steel girders did not show so large a percentage of greater strength over the iron girders as did this material in the specimen over the iron in the specimen.

Strength of Old Wire.—Pieces of wire cable of the Fairmount Suspension Bridge, recently taken down at Philadelphia, after being in use some forty years, were found to be fully equal in tenacity, elasticity, and ductility to the best wire of that size now in the market. *

Basic Steel for Boiler Tubes.—The American Tube and Iron Company of Middletown, Pennsylvania, has been making experiments on the use of basic Bessemer steel for boiler tubes with the most satisfactory results. The experiments made with English basic steel were unsatisfactory, as the steel was harder, and was difficult to weld properly, although when finished it was found to be quite ductile. The greater hardness is due to the higher percentage of carbon and phosphorus. The phosphorus in the English basic steel is about 0·14 per cent. against 0·02 in the American; while the manganese is practically the same in both, about 0·3 per cent.†

V.—*ANALYSIS OF IRON AND STEEL, &c.*

Determination of Sulphur in Steel.—At the Cincinnati meeting of the American Institute of Mining Engineers, Magnus Troilius described the method employed at Midvale Steel Works, Philadelphia, for the estimation of sulphur in steel.

Ten grammes of drillings are put into a half litre flask having a long neck. This is then connected with a wide glass tube, which, in its turn, is connected with absorption bulbs containing hydrochloride acid and about 5 c. c. of bromine. The bulbs are in connection with a long glass tube to carry off the bromine fumes. The connections being made, 100 c. c. of boiling water are run into the flask through a thistle tube, which drives out the air; 108 c. c. of hydrochloride acid are then run in. When

* *The Mechanical World*, vol. xvi. p. 115.

† *Engineering and Mining Journal*, vol. xxxvii. p. 279.

the gas begins to run slowly through the absorption bulbs, heat is employed until boiling gradually ensues. The steel being dissolved, the apparatus is disconnected, and the contents of the bulbs are run out into a beaker of 100 c.c. capacity, into which a few c.c. of a solution of barium chloride had been previously placed. The solution is then heated until all the bromine has been driven off, and the barium sulphate is then filtered and weighed.

Incrustations on Pig Iron.—Peculiar crusts appearing on iron made at Glendon and Pequest were so entirely new to the managers of the works that some analyses of them were made.* At Pequest the iron varied in silicon from 0·84 per cent. in No. 1 Foundry to 0·51 per cent. in grey forge; in phosphorus from 0·81 to 0·55 per cent.; sulphur, 0·035 per cent.; and manganese, 0·375 per cent. After running the pig into the moulds, the black crust began to show itself, seeming to exude from the pigs, till finally, when cold enough to break, it completely covered the face of the pigs. At this time it was a dense black, but after some exposure to the air it acquired a purplish tinge. The higher the grade of the iron, the heavier was the coating; being very heavy on foundry iron, a little less on grey forge, hardly perceptible on mottled, while on white iron it was entirely wanting. After some experience, it served to give a very correct idea as to what the grade was before the iron was broken, and was a much more trustworthy guide than the appearance of the metal while running.

A sample, scraped off the faces of the pigs, gave on analysis the following results:—

	Pequest.		Glendon.
Ferric oxide	38·14	...	32·11
Silica	45·69	...	50·36
Alumina	3·56	...	...
Oxide of manganese	4·97	...	9·96
Lime	1·61	...	0·10
Magnesia	0·66	...	0·00
Titanic anhydride	5·59	...	5·77
Phosphoric anhydride	0·06	...	0·12
Vanadic anhydride	0·48	...	0·15
Moisture	0·24	...	...
Totals	101·00	..	98·57

The crusts on the iron at Glendon do not differ much in appearance and mode of occurrence from those described from Pequest, except that they are best seen on No. 2 iron. Both samples were largely contaminated with sand and dust from the pig-bed.

* Paper read by Messrs. F. Firmstone and K. Robertson at the Cincinnati Meeting of the American Institute of Mining Engineers.

These crusts are very common on the iron at Glendon, and the iron that shows them is sure to be of good quality, and especially is sure to chill well; but the absence of the crust is no proof that the iron will not be good in that respect.*

Highly Phosphoric Pig Iron.—In a paper read before the American Institute of Mining Engineers, Prof. N. W. Lord states that iron with a rather unusual percentage of phosphorus has recently been made at one or two places in Ohio. The first specimen examined came from Moxahala furnace, in Perry County. The ore smelted was a blue carbonate, very free from silica, and gave, on analysis, from 2 to 3 per cent. of phosphorus. The furnace company had trusted entirely to old analyses made on weathered ore from the outcrop. The result of the first run of the furnace was an exceedingly brittle iron in large whitish-grey crystals. It contained 4·90 per cent. of phosphorus. Only a limited quantity was made, and the furnace was subsequently run mainly on Lake Superior ore.

The second case of such iron occurred at Mount Vernon furnace. The ore was a blue carbonate, similar to that described above. The iron made was of a pure tin-white colour, and showed large crystals without a trace of the grain of ordinary pig iron. It contained 4·30 per cent. of phosphorus, and 0·05 per cent. of silicon. The low percentage of silicon is remarkable.†

Determination of Manganese in Spiegeleisen.—At the Cincinnati meeting of the American Institute of Mining Engineers, G. C. Stone gave the following results of a further series of estimations of the manganese contained in spiegeleisen as an addition to those previously given:—‡

Method Used.	Manganese Found.
Acetate, sulphate, and carbonate	13·03 13·26
Acetate and bromine	13·72
Oxide of zinc, potassium, permanganate	13·10 13·10 13·75 13·69 14·08 14·02 14·02
Acetate and phosphate	13·68 13·65 13·33
Potassium chlorate and phosphate	14·76 15·04
Potassium chlorate, bromine, and phosphate	13·68
Potassium chlorate and phosphate	13·53 13·68

* *Engineering and Mining Journal*, vol. xxxvii. p. 140.
† *Ibid.*, vol. xxxvii. p. 332.
‡ This *Journal*, 1883, p. 366.

Method Used.	Manganese Found.
Pattison's method	13·13
Acetate, bromine, and phosphate	13·63
Potassium chlorate and phosphate	13·36
Acetate and phosphate	13·40
Oxide of zinc, potassium permanganate	13·21 13·02 13·13 13·21 13·05

VI.—*STATISTICS.*

Iron Ore.—The total shipments of iron ore from the Lake Superior mines in 1883 is stated by the *Marquette Mining Journal* to have been 2,351,372 tons, showing a decrease of 596,935 tons compared with 1882.

Pig Iron.—The production of pig iron in the United States is estimated by Mr. Swank, the secretary of the American Iron and Steel Association,* to have been 4,995,510 tons, or 5,146,972 net tons of 2000 lbs. The fuel used was as follows:—

	Tons.
Bituminous coal	2,689,650
Anthracite	1,885,596
Charcoal	571,726
Total	5,146,972

The following table shows the production of pig iron by States in 1883:—

States.	Net Tons.	States.	Net Tons.
Pennsylvania	2,638,891	Georgia	45,364
Ohio	679,643	Colorado	24,680
New York	331,964	Connecticut	19,976
Illinois	237,657	Massachusetts	10,760
Michigan	173,185	Indiana	9,950
Alabama	172,465	Minnesota	8,000
Virginia	152,907	Oregon	7,000
New Jersey	138,773	California	5,327
Tennessee	133,963	Maine	4,400
Missouri	103,296	Texas	2,381
West Virginia	88,398	Washington	2,317
Kentucky	54,629		
Wisconsin	51,893		
Maryland	49,153	Total	5,146,972

At the close of 1883 there were 307 furnaces in blast, and 376 out of blast. Nineteen blast furnaces were in course of erection. The following table shows the number of furnaces in and out of blast at the close of 1883, as compared with the close of 1882:—

* "Statistics of the American and Foreign Iron Trades for 1883." By J. M. Swank Philadelphia.

Kind of Fuel.	1882. In Blast.	1882. Out of Blast.	1882. Total.	1883. In Blast.	1883. Out of Blast.	1883. Total.
Bituminous coal	127	83	210	105	116	221
Anthracite .	161	64	225	118	104	222
Charcoal . .	129	123	252	84	156	240
Total . .	417	270	687	307	376	683

The Consumption of Pig Iron in 1883.—The consumption of pig iron in the United States in 1883 is calculated by Mr. Swank at 4,834,740 tons.

Stocks of Pig Iron.—On December 31st, 1883, 533,800 net tons of pig iron were unsold. Of this quantity 171,802 tons were produced with bituminous fuel, 178,020 tons with anthracite, and 183,978 tons with charcoal.

Iron and Steel Rails.—The production of all kinds of rails in 1883 was as follows :—

	Net Tons.
Iron rails	64,954
Bessemer steel rails	1,286,554
Open-hearth steel rails	9,186
Total	1,360,694

Of this quantity, Pennsylvania made 63 per cent. and Illinois 17 per cent. The approximate consumption of all kinds of rails in the United States during the year 1883 was 1,399,671 net tons, 1,360,694 tons of which were made in the United States.

Bessemer Steel.—In 1883 the production of Bessemer steel in the United States amounted to 1,654,627 net tons, or 41,823 tons less than in 1882. 15 Bessemer works were in operation, embracing in all 38 converters.

Miscellaneous Steel.—The production of crucible steel ingots in 1883 was 80,455 net tons. Six States made crucible steel : Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, and Ohio. The production of open-hearth steel was 133,679 net tons, a decrease of 26,863 tons upon the production of 1882. 5598 net tons of blister, puddled, and patented steel were also produced. The total production of steel of all kinds in 1883 was 1,874,359 net tons.

Rolled Iron.—By the term rolled iron is included cut nails and spikes; bar, shaped, bolt, and hoop iron, and rolled axes; plate and sheet iron; and all sizes of iron rails. Omitting iron rails, the production of rolled iron in 1883 was 2,283,920 tons.

Details of the production are given.

	Net Tons.
Bar and shaped iron	1,511,422
Plate and sheet iron	384,362
Cut nails	388,136
Iron rails	64,954
Total . . .	2,348,874

Blooms.—Blooms from ore are made chiefly in the Champlain district of New York, and blooms from pig and scrap iron are made chiefly in Pennsylvania. The former are used for conversion into plate and sheet iron, iron wire, and open-hearth and crucible steel; the latter almost entirely for conversion into plates and sheets. In 1883 the total production was 74,758 net tons; 35,237 tons of this quantity were blooms from ore, and 39,521 tons blooms from pig and scrap iron.

Summary.—The production of iron and steel in the United States in 1883 is given below in comparison with that of 1882:—

	1882.	1883.
	Net Tons.	Net Tons.
Pig iron	5,178,122	5,146,972
Rolled iron, excluding rails . . .	2,265,957	2,283,920
Bessemer steel rails	1,438,155	1,286,554
Open-hearth steel rails	22,765	9,186
Iron rails	227,874	64,954
Crucible steel ingots	6,147,097	7,762,737
Open-hearth steel ingots	85,089	80,455
Bessemer steel ingots	160,542	133,679
Blooms	1,696,450	1,654,627
	91,293	74,758

Pennsylvania Coal.—According to Hon. J. B. McCamant,* Chief of the Bureau of Industrial Statistics at Harrisburg, the production of anthracite in Pennsylvania in 1883 was 30,154,546 tons. 310 collieries were in operation, employing 87,308 persons. The production of bituminous coal was 18,729,817 tons from 381 collieries. The total number of persons employed was 45,454. The production of coke was 3,380,872 tons from 10,617 coke-ovens.

* *Engineering and Mining Journal*, vol. xxxvii. p. 353.

	Charcoal.					Anthracite.					Bituminous Coal or Coke.				
	Total number.	No. in blast.	Capacity per week.	No. out of blast.	Capacity per week.	Total number.	No. in blast.	Capacity per week.	No. out of blast.	Capacity per week.	Total number.	No. in blast.	Capacity per week.	No. out of blast.	Capacity per week.
New England	15	4	335	11	870	1	0	...	1	160	...	...	...	...	...
New York	15	5	439	10	764	41	16	4,275	25	6.125	...	...	...	...	...
New Jersey	...	...	...	...	...	18	3	940	15	3,925	...	...	...	...	...
Spiegel	...	...	...	...	...	3	2	110	1	55	...	...	...	...	...
Pennsylvania	36	13	705	23	1,344	...	...	...	...	...	...	...	...	...	...
Lehigh Valley	...	...	...	...	...	51	25	7,745	26	6,630	...	...	...	...	...
Schuylkill Valley	...	...	...	...	...	46	18	4,685	28	6,070	...	...	...	...	...
Upper Susquehanna Valley	...	...	...	...	...	25	11	3,109	14	3,050	...	...	...	...	...
Lower Susquehanna Valley	...	...	...	...	...	41	23	5,665	18	2,350	...	...	...	...	...
Pittsburg	...	...	...	...	...	...	...	...	...	...	17	10	7,730	7	6,100
Allegheny Valley	...	...	...	...	...	...	...	...	...	...	4	2	585	2	162
Shenango Valley	...	...	...	...	...	...	...	..	...	...	30	10	5,397	20	6,073
Youghiogheny Valley	...	...	...	...	...	...	...	...	...	...	6	4	1,321	2	575
Juniata and Conemaugh Valley	...	...	...	...	...	...	...	...	...	...	26	14	4,569	12	2,770
Maryland	16	7	575	9	600	5	3	420	2	400	2	0	...	2	230
Virginia	31	9	378	22	1,175	...	...	...	...	...	13	6	2,851	7	1,920
North Carolina	5	0	...	5	290	...	...	...	...	...	...	...	...	...	...
West Virginia	6	0	...	6	625	...	...	...	...	...	7	1	400	6	3,326
Ohio—Mahoning Valley	...	...	...	...	...	...	...	...	...	...	18	8	3,060	10	3,820
Eastern, Central and Northern	...	...	...	...	...	...	...	...	...	...	20	11	4,860	9	3,150
Hocking Valley	...	...	...	...	...	...	...	...	...	...	15	1	112	14	2,490
Hanging Rock	28	9	860	19	1,710	...	...	...	...	...	15	7	1,250	8	1,385
Miscellaneous	3	0	...	3	263	...	...	...	...	...	...	...	...	...	...
Kentucky	...	...	...	...	...	...	...	...	...	...	3	2	750	1	400
Hanging Rock	7	2	220	5	445	...	...	...	...	...	...	...	...	...	...
Western region and miscellaneous	8	0	...	8	675	...	...	...	...	...	...	...	...	...	...
Tennessee	11	1	160	10	885	...	...	...	...	...	8	5	2,830	3	770
Georgia	6	1	200	5	257	...	...	...	...	...	1	1	600	0	...
Alabama	12	7	1,560	5	830	...	...	...	...	...	9	4	2,390	5	2,110
Indiana	1	0	...	1	140	...	...	...	...	...	2	1	200	1	200
Illinois	...	...	...	...	...	...	...	...	...	...	16	8	7,175	8	4,800
Michigan	26	15	3,258	11	2,060	...	...	...	...	...	2	0	...	2	580
Wisconsin	12	3	390	9	1,131	...	...	...	...	...	3	2	1,000	1	540
Minnesota	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Missouri	9	4	1,200	5	688	...	...	...	...	...	8	1	550	7	3,810
Texas	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Utah	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Oregon	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Colorado	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...
Total	251	80	10,280	167	14,75	231	101	26,949	130	28,765	226	98	47.630	127	45,211

Railway Construction in 1883.—During the year 1883, 6869 miles of railway were constructed in the United States. The details were as follows: *—

	Lines.	Miles.
New England States	13	84·2
Eastern Middle ,,	38	770·2
Middle Western ,,	59	1344·1
,, Southern ,,	45	1212·0
Pacific Belt	19	1046·3
Missouri ,,	30	835·5
Kansas ,,	35	834·5
Colorado ,,	18	742·8
Totals	257	6869·6

Iron Wheels.—The number of iron and steel car-wheels in use in the United States is estimated at 10,000,000. About 1,250,000 are worn each year, requiring about 312,500 tons of iron, about $\frac{11}{12}$ths of which are supplied by the used-up wheels themselves, which are broken up and recast.†

* *The Iron Age*, May 15, p. 19.
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